IN TWO SECTIONS—SECTION ONE

MECHANICAL ENGINEERING

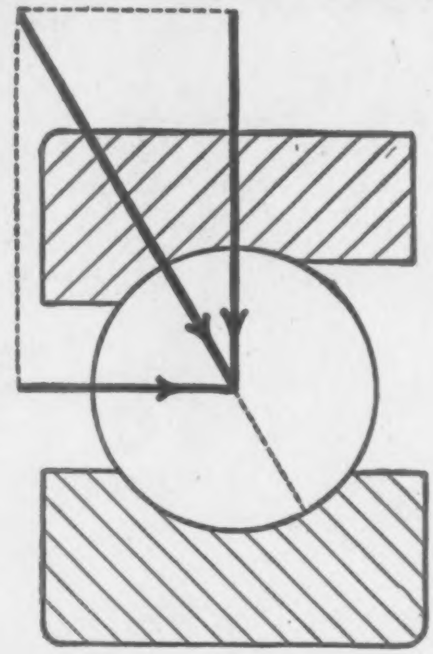
THE JOURNAL OF THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS

A. S. M. E. SPRING MEETING
ST. LOUIS, MAY 24 TO 27

APRIL 1920

PUBLISHED MONTHLY BY THE SOCIETY
29 WEST 39TH STREET, NEW YORK, U.S.A.

The Resultant Is a Single Load in a Single Direction



One of the elementary principles of mechanics is that the combination of two forces exerted in different directions IS a single force acting in one direction. Likewise, the fundamental principle of the radio-thrust bearing is the inclining of the load line of the balls into the general direction of the line of force through which the Simple Resultant load is received. Thus, in Gurney Ball Bearings

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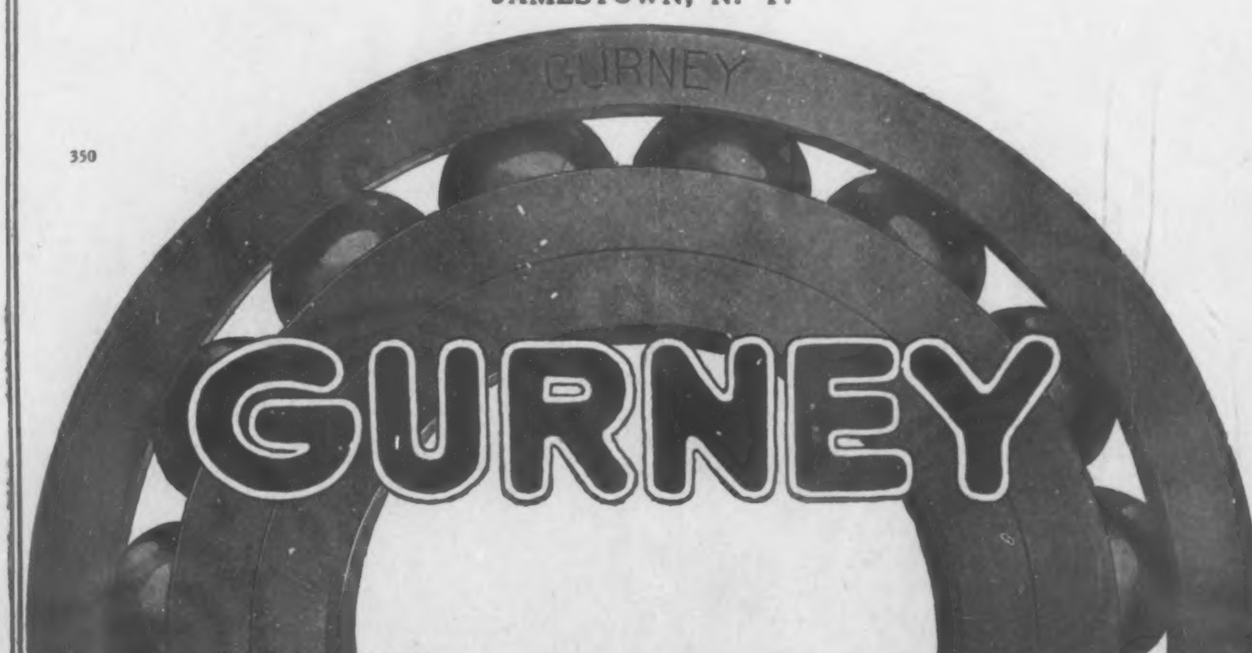

Mechanical Engineering

The Journal of The American Society of Mechanical Engineers

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Spring Meeting of the A. S. M. E.

St. Louis, Mo., May 24-27

A tentative program for the Spring Meeting of The American Society of Mechanical Engineers will be found in Section Two of this issue, together with particulars of an excursion to the plant of the Mississippi River Power Company at Keokuk. A strong professional program has been arranged for the meeting and many attractive entertainment features are to be provided by the St. Louis Committee.

Contributors and Contributions in the April Number

Charles de Freminville, Engineer of the Schneider Works, the Greatest Industrial Organization of France

When M. de Freminville received Honorary Membership in The American Society of Mechanical Engineers last December he delivered a scholarly paper before the Society on the Reliability of Materials and Mechanism of Fractures. When he returned to France he took his manuscript with him for revision and it has just been received in its finished form. M. de Freminville was a pioneer in the construction of steel railway cars, later was associated in the manufacture of automobiles, and during the war in the production of guns and shells. These various activities called for an intensive study of the characteristics of steels, upon which he has become an authority of international fame.

Otis L. McIntyre on the Use of Pulverized Coal at High Altitudes

Three continents are represented in this number of MECHANICAL ENGINEERING: Europe, North America, and South America. The paper from the latter is upon experiences in the burning of pulverized coal at the high altitude of 14,000 ft. It describes experiments which led to the installation of pulverized-coal apparatus for the metallurgical furnaces of the Cerro de Pasco Copper Corporation and explains the difficulties actually experienced in the operation of the plant.

F. W. Caldwell and E. N. Fales, of the Air Service, U. S. A., Tell of Basic Results Obtained from Experiments on the Wind Tunnel at McCook Field, Dayton, O.

The wind tunnel at McCook Field is notable for the high velocity of air used (500 m.p.h.) and the visualizing of the air flow by providing means for the condensation of the vapor in the air. In their remarkable paper, contributed to this number, the authors describe the wind tunnel and give data which enable one to form a clear conception of the conditions surrounding the operation of propellers.

The Dissipation of Heat from Various Surfaces Discussed by T. S. Taylor

In the January number of MECHANICAL ENGINEERING Mr. Taylor commented briefly on the value of sheet asbestos on hot-air pipes. These comments called forth considerable discussion and the experiments which formed the basis of Mr. Taylor's contribution are now described in full in this number. They show that wrapping a thickness of 0.2 in. of sheet asbestos around hot-air pipes is no better than leaving the pipes uncovered, and that at least twice that thickness is necessary to effect a saving of 25 per cent. Mr. Taylor also discusses the effect of air velocity and the angle at which air strikes the pipes.

Chester B. Lord Proposes Method for Securing Tight-Fitting Threads

At the last Annual Meeting of The American Society of Mechanical Engineers Mr. Lord, who is the consulting mechanical engineer of the Research Engineering Co. of St. Louis, presented a paper describing a new type of rotary compressor. To this number he has contributed a paper on Tight-Fitting Threads for Bolts and Nuts, in which he discusses the fundamental principles involved in the manufacture of threads. Mr. Lord has had wide experience in manufacturing problems and he urges the use of threads of different angles for the bolt and nut respectively; this is for the purpose of providing room for the metal to flow, and thus produce a fit which will not loosen under the action of vibration.

Glenn B. Warren on Simplification of Venturi-Meter Calculations

The author had occasion to measure by means of a venturi meter the amount of compressed air used in connection with research work. He devised for this a simple method for the calculations involved which are applicable to any venturi meter used for the measurement of a gas. This method forms the subject of the paper.

Record Altitude Flight of Major R. W. Schroeder

Col. Thurman H. Bane, Commanding Officer of McCook Field, gives an authoritative and interesting account of Major Schroeder's recent flight to an altitude of over 36,000 ft. The article outlines the engineering problems involved and lays particular stress on the importance of the supercharger.

Standard Sizes for Shafting Proposed by Committee of A.S.M.E.

As a result of the investigations of the Committee of the A.S.M.E. on War Industries Readjustment it became apparent that an immense saving in power-transmission materials could be effected by the standardization of shafting sizes. A committee was appointed to investigate the matter, whose report appears in this number.

MECHANICAL ENGINEERING

THE JOURNAL OF THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS

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Reliability of Materials and Mechanism of Fractures

Behavior of Materials Under Test and in Actual Use Discussed by Distinguished French Engineer

By CHARLES DE FREMINVILLE[1], PARIS, FRANCE

It is a common experience that the behavior of materials in practice does not always agree with their behavior under test; designs worked out from data secured from test pieces have not always proved satisfactory, and actual machines have had to be modified from the experience of practice. The differences between test predictions and actual results are set forth in the following paper, and it is shown that the reasons for the discrepancy between test and actual conditions can be determined by an analysis of the mechanism of fractures of the test pieces and of actual specimens. Such an analysis reveals the fact that the mechanism of the fracture follows certain laws which can be formulated. The paper also deals with methods of designing members so that stresses in them do not conflict with the laws of mechanism of fracture. Pieces can be so designed and so assembled that the stresses in them largely avoid the conditions of fracture, and it is significant that when such design and assembling is carried out, the behavior of the actual machines is much more similar to the behavior of the test pieces themselves.

WHEN the author was invited to read a technical paper before The American Society of Mechanical Engineers the first subject which came to his mind was, The Reliability of Materials, chiefly because of his previous experience in the use of metals and with the testing of metals. If that word "reliable" impressed itself upon his mind, it was certainly because it is a word of which he has realized the full meaning in America, where the people are always looking for something reliable: reliable information, reliable products, reliable men; a country in which he found so many reliable friends, and which has proved herself so prominently and so thoroughly reliable in her immense effort to save the mutual ideal of civilization of France and America, which cannot conceive Science associated with an ideal other than Liberty.

Reliability is the quality we desire in the metals we use, but it is very difficult to ascertain it through a short test. The reliability of materials is like the reliability of friends. Whatever brilliant qualities they may exhibit, their reliability is known only in the long run, so that in the case of an apparent failure, the qualities of a metal, like those of a friend, should not be questioned too quickly. It is not enough to know the intrinsic qualities of the metal; a very careful study of the circumstances under which the failure occurred must also be made, and it is this fact which has made the study of fractures and of the mechanism of fractures one of great interest to the author.

During the early days of the automobile industry the problem of resistance of materials began to be considered in a new light. The first motor cars that were built were designed with factors of safety then generally accepted for the resistance of medium-carbon steel. But the engineer soon came into contact with the sportsman and was tempted to put into the gearing a stress much greater than the one for which it had been made. One of the problems to be solved, therefore, was to secure a material which could safely be used for gears.

At that time steel makers had produced, among certain other new products, ternary steels, which showed brilliant promises of new qualities if the results of the laboratory tests to which they had been submitted could be taken as a proof of their reliability.

Viewing the question of material for motor cars in a general manner, the constituent parts appeared to belong to two distinct classes. The first included such parts as gears, crankshafts, connecting rods, etc., which had to withstand severe normal shocks. Also only a small amount of wear was allowable and the class of accidents to which they were liable was limited, being chiefly those of seizing or an encounter with stray nuts or bolts.

The parts of the second class did not have much stress imposed upon them in ordinary service, but they did have to meet with what can be termed "normal accidents," and were therefore expected to bend to a certain extent without ceasing to fulfill their duty. To this class belonged front axles and, more generally, all the parts connected with the steering mechanism. For these, the "normal accident" can happen very frequently. It is almost impossible to say that the wheel of a car will not come rather abruptly into contact with a curbstone, or even with the wheel of another car. In such case something must yield or break. It is of course but natural to hope that something will yield and that this yielding has been foreseen; also that it will take place on a piece easily seen and easily replaced, and that the material of which the piece is made will not cease to be reliable.

The impact test, to which attention was directed at that time in France by M. Considère and later by M. Frémont, seemed to be a very convenient method for ascertaining the characteristics of the parts of each class. The impact test, however, was devised primarily for soft steel and had to be adapted for very hard steel. But by making use of the impact test it was possible to select for the parts of the first class a grade of steel which only fractured after a very small amount of deformation, and this could be considered as a very excellent quality for the parts of this class.

The parts of the second class were expected to bend under the impact test to a very great extent, and it was easy to find wrought iron or mild steel possessing this characteristic, although the reliability of these materials for the use considered is a matter open to discussion. But here again the problem became complicated, because there were those who seemed reluctant to admit that some of the parts had to bend easily under certain circumstances and that a limited amount of toughness was not desirable, inasmuch as the steel maker pretended to have grades of steel uniting in a rare degree ductility with toughness.

The tensile tests of these steels showed a high ultimate strength and a great elongation. The impact test showed that a consider-

[1] Architectural and Industrial Engineer. Consulting Engineer, Schneider Works. Hon.Mem.Am.Soc.M.E.

Presented at the Annual Meeting, New York, December 1919, of THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS. All papers are subject to revision.

able amount of energy had been absorbed by the test piece, which gave a great amount of distortion. It is evident that if it had been possible to have a diagram of the impact test, showing at every moment what was the amount of stress corresponding to a given deflection, the matter would have been made very much clearer. But since there was no machine that would give such a

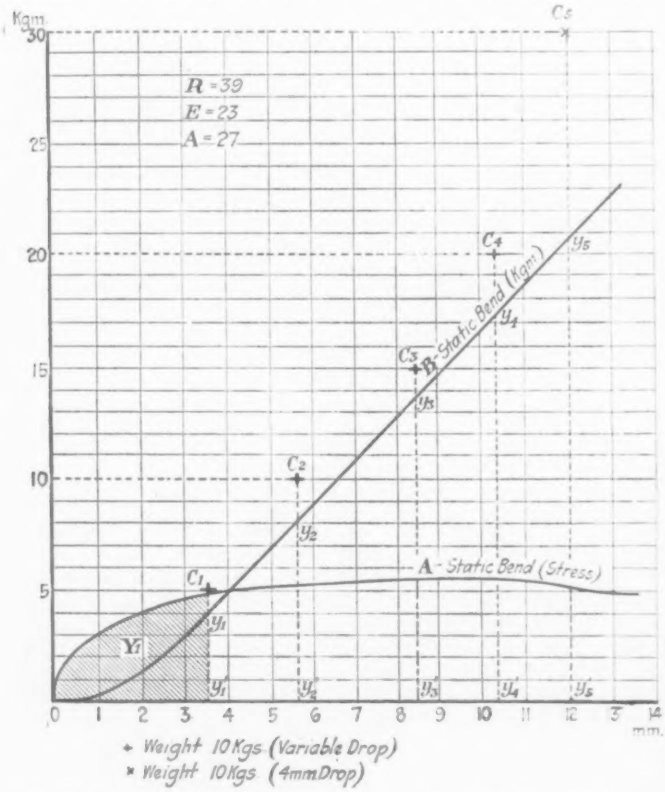


FIG. 1 DIAGRAM FOR COMPARING THE RESULTS OF STATIC BEND AND DROP BEND TESTS

diagram, a substitute was found in a static bending machine registering the amount of energy taken in the deformation process, for it was possible to ascertain that in all the cases which had to

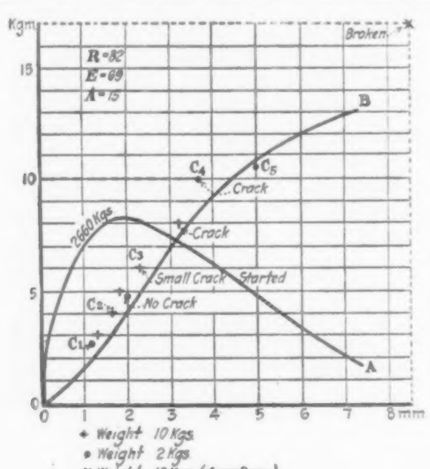


FIG. 2 DIAGRAM FOR COMPARING THE RESULTS OF STATIC BEND AND DROP BEND TESTS

be investigated, the number of kilogram-meters absorbed was practically the same as in a quick bend or in a drop test. So far as the appearance of the fracture was concerned there was no perceptible difference in either case, which showed that the metal which seemed to possess ductility and toughness did not possess these characteristics to the extent believed.[1]

Figs. 1 and 2 are diagrams for comparing the results obtained by drop tests and quick-bend tests on notched test pieces. In these diagrams the ordinates of curves *A* are proportional to loads corresponding to deflections shown on the abscissa scale. In curves *B* (which are the integrals of curves *A*,—ordinates $y_1y'_1$, $y_2y'_2$, etc., being proportional to surface Y and so on) the amount

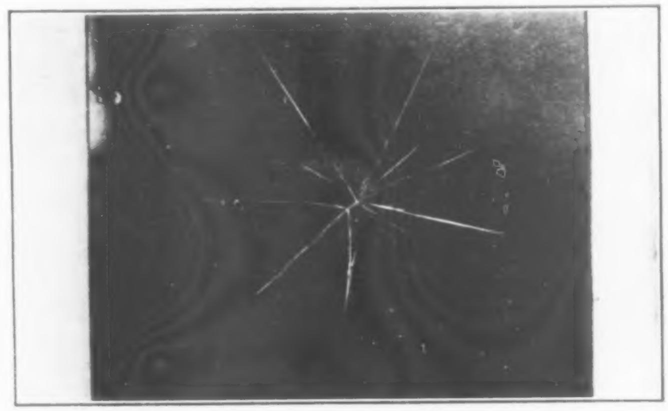


FIG. 3 RESULT OF SHARP SHOCK ON A GLASS VESSEL

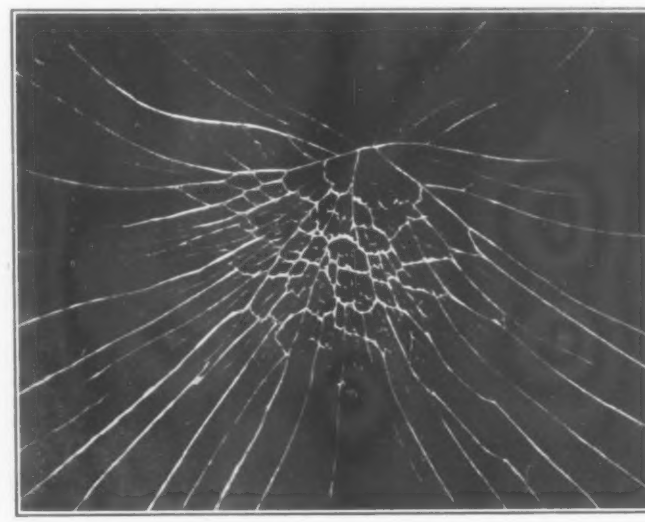


FIG. 4 DEVELOPMENT OF THE FRACTURE RESULTING FROM A SHOCK ON A THIN SHEET OF GLASS

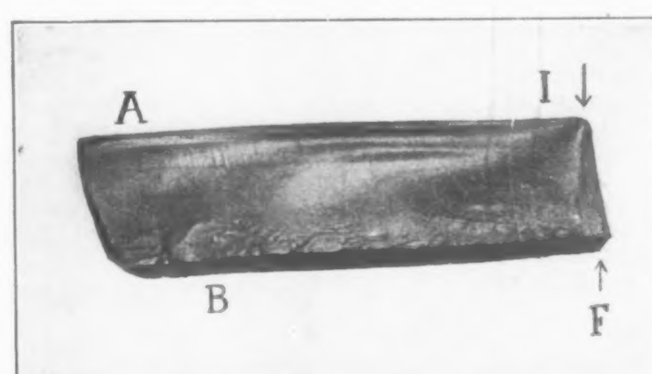


FIG. 5 FRACTURE SURFACE IN A SLAB OF GLASS

of energy consumed in the bending test is given for each value of the deflection. The ordinates y'_1C_1, y'_2C_2, etc., are proportional to the amount of energy absorbed by the drop test for the same

[1] The author has recently learned that the same idea of interpreting a drop test by means of a diagram given by a static bend test has been successfully used in this country for testing rails, and he believes that it can be used in many instances.

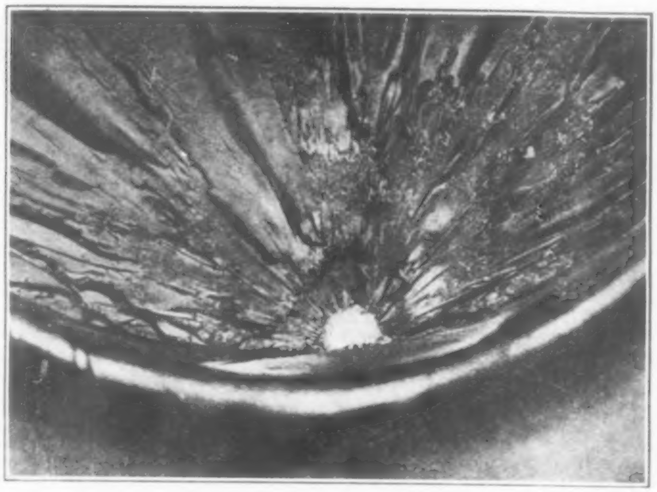


Fig. 6 Small Splintering Focus—Glass

Fig. 7 Splintering Focus—Glass

Fig. 8 Fracture in Judea Bitumen

deflection, as measured in the bend test, and can be easily compared with $y_1y'_1$, $y_2y'_2$. The energy absorbed in the drop test appears to be only slightly greater than that absorbed in the quick-bend test, but the process has followed the same course in both cases, and the difference may be attributed to errors in the experimental work.

Fig. 1 is a diagram of a test of wrought iron or mild steel in which the amount of stress necessary to obtain a given deflection remains constant over a long range. This is the type of material which can be expected to give good results for parts of the second class.

Fig. 2 is a diagram of a test of a steel with a certain amount of ductility, in which the energy consumed for a given deflection appears to be greater than in the case of Fig. 1, and which was offered for parts of the second class. It should be noted that in

Fig. 9 Fracture in Glass

Fig. 2 curve A is absolutely different from curve A of Fig. 1, as it shows that a maximum amount of the energy is absorbed after a small deflection has been obtained. This maximum is the point where the piece begins to show a crack, which of course did not exist in the test piece whose diagram is shown in Fig. 1.

Parts of the second class made of this metal proved a decided failure. Even without experiencing the "normal accidents" which they were expected to withstand, they showed a great tendency to crack without the slightest deformation, which method of fracture has been called *fissillité* by the late M. Brustlein, of the Jacob Holtzer firm, Unieux, France.

By looking closely into the fracture of the broken test piece, which was supposed to possess ductility and toughness, it could be seen that most of the distortion, or flowing of the metal, had taken place not before the fracture was started, but during the process of extension of the fracture, and this gave to the amount of energy recorded an altogether different meaning. In this case

the failure of the material could be traced to a bad interpretation of the test, but other failures were encountered which could not be traced to the quality of the metal used. Typical among these

Fig. 10 Fracture in Judea Bitumen

was the sudden snapping of levers, under conditions which could be specified but which were difficult to explain. The impact test, like others, could not give a clue as to reliability in certain circumstances.

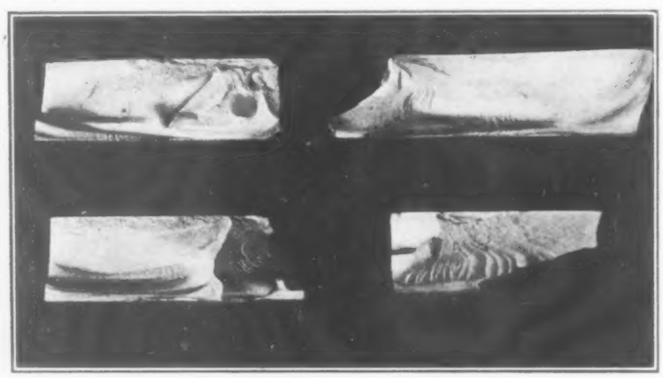


Fig. 12 Fractures in Tool Steel

The Study of Fractures

The uncertainties in the behavior of material, the propagation of a crack without any distortion of the piece, the sudden snapping of a rod without any perceptible alteration in the neighbor-

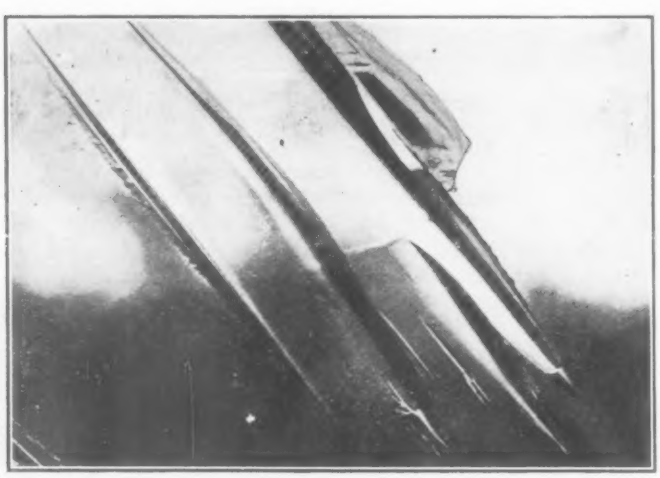
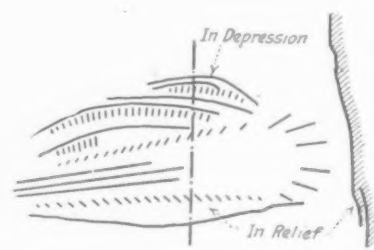


Fig. 13 Rents Formed Under the Main Surface in Glass

hood, even the changes which were produced in brittleness under heat treatment, appeared to be difficult to account for, and it seemed to the author to be worth while to add to the theoretical views of the question by making, as far as possible, a thorough study of the fracture itself, which would tell, in some cases, the story of the failure.

It is frequently believed that fracture is a form of failure of such peculiar character as to escape all rules. However, the attention of the author was first attracted by the very regular fractures of sandstone, which is used extensively in France for pavements, and which so resemble one another that they seem to be real diagrams of what has happened during the rupture. Moreover, a certain number of peculiarities of the fractures were found to be common to both sandstone and steel. It was also noticed that these same features were found in glass fractures, in which they could be observed with great accuracy; also that they were still easier to observe in Judea bitumen, where the breakage was produced very easily. A further study has shown that the fractures developed in an identical manner in these various materials.

It is not possible in the limited time at the disposal of the author to go thoroughly into the subject of the study of fractures, and as a result attention can only be called to some of the main features. Fig. 3 shows a fracture developed in a glass vessel by a sharp shock. In this should be noted the symmetry of the surfaces originated and the peculiar disposition of the starting points of these surfaces from both ends of a small line to which the surfaces are tangent. Fig. 4 shows the development of the fracture resulting from a similar shock in a thin sheet of glass. Here great symmetry is seen, the network also originates from a small line, and some of the surfaces extend entirely through the glass, some only partially.



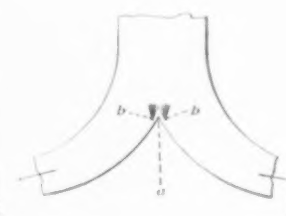


Fig. 11 Scheme of Fracture in Judea Bitumen

Fig. 14 Scheme of Tearing, With Cracks That Accompany It

Fig. 5 is taken from a slab of glass broken in the same manner. It shows one of the surfaces dividing the slab into pieces, which was also partially cut by other surfaces. In this particular case the blow was given at I on the top of the slab, and it will be seen that the small line, noted in the previous figures as the origin of all the cracks, is situated at F at the opposite side of the surface. It presents a very remarkable appearance and the general disposition of the surface induces us to believe that the fracture originated in that region.

Figs. 6 and 7 show in great detail other specimens of very peculiar surfaces, which illustrate very clearly that there is a starting point of the fracture. These examples enable us to see that one of the main surfaces cutting the test sample has not expanded at one stretch, but is formed by surfaces overlapping each other like the blades of a fan. This is made still more evident by the fracture shown in Figs. 8 and 9. These surfaces overlap each other at distances often smaller than a hundredth of an inch, and by making use of the method called *recoupement* (recutting) by the geologists, it is possible to follow the successive order in which the various elements of the fractures have developed.

Fig. 11 shows in greater detail one of these surfaces, and enables us to point out some of its special features. Part of the surface is bright and part dull. A study of the bright part can be made from Fig. 10, which shows a standard fracture in Judea bitumen. It is very easy to follow the surfaces overlapping each other, as is shown by the scheme in Fig. 11. The general arrange-

ment of the surfaces bears a very close resemblance to the surface of water as it runs in a culvert, passes over a dam, or expands in a shallow pond.

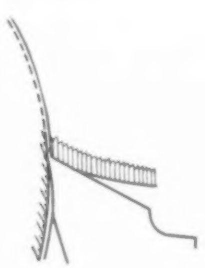
The same arrangements of fractures, overlapping surfaces, foci, etc., which are easily observed in glass and Judea bitumen are also met with in tool steel, as shown in Fig. 12.

We find that the dull part gives the impression that it has been rent or torn away, while the bright surface seems to have been carefully cut. Fig. 13 shows how the dull surface is originated by small rents coming from under the surface. If now we come back to the focus of Figs. 6, 7 and 8, and look for the point where it has been originated we find that it also lies under the surface.

Fig. 14 shows what takes place in the tearing of a tough substance such as gelatine. The cracking *bb* travels ahead of the parting at *a* and prepares the way for its advance.

Fig. 15 is another and striking example of the tearing of a tough material. The parting at the edge of the tool has been made possible by a "cracking" similar to that shown in Fig. 14. The sketch in Fig. 16 shows the scheme of the formation of the steel chip.

But how can a bright surface be produced? How can the cutting process be carried on without the sub-surface cracking? How can surfaces be cut which run parallel within such small distance as the ones we have noted? The only explanation which seems to be satisfactory is that the cutting power is a vibratory motion of the surfaces of the fracture, so long as they do not join each other.



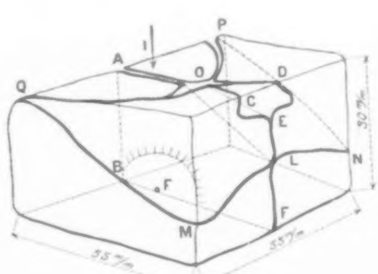


FIG. 16 SCHEME OF STEEL CHIP

FIG. 18 OUTLINE OF THE FRACTURE OF A BITUMEN BLOCK

Fig. 17 shows a very typical arrangement of the fracture surfaces in a bitumen block and Fig. 18 gives an outline of the different parts. The same arrangement is constantly found in steel fractures, Fig. 19 showing a similar fracture in a piece of a steel rail broken under a drop test.

STRESS AND STRAIN

What are the conclusions to be drawn from this brief study of the mechanism of fractures? How can it pretend to be a contribution to the science of resistance of materials? In a general way, by showing the succession of the phenomena which have taken place during the spreading of the fracture, it affords an experimental proof that the straining effects are more detrimental to the material than mere stress. This is in accordance with what has been shown by a purely mathematical study of the question.

In case of an impact fracture, be it in a piece of glass or in a piece of steel, we find the starting point of the fracture under the surface, although the maximum stress must certainly be located on the surface itself.

In the case of a piece subjected to tension only if a comparison is made with the fractures already considered it will show that fracture has originated along the axis of the test piece (see Fig. 20). The surface of the test piece itself sustains a very important stress, but without being subjected to the strains resulting from the contact of layers undergoing uneven stresses, flowing, so to speak, to give the reduction of area.

The predominance of the internal or straining action is no less striking in the case of a rent where the straining effect travels in advance of the stress which could be originated at the separating

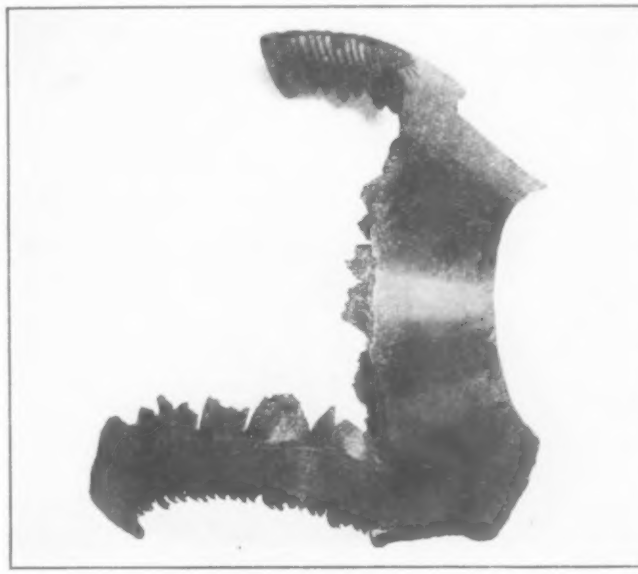


FIG. 15 STEEL CHIP

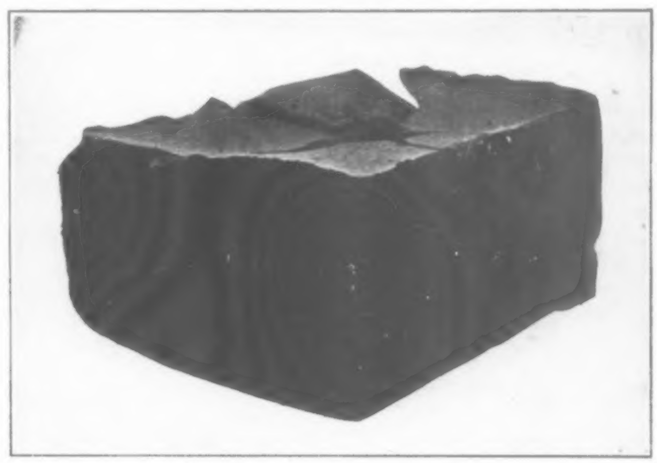


FIG. 17 FRACTURE OF A BITUMEN BLOCK

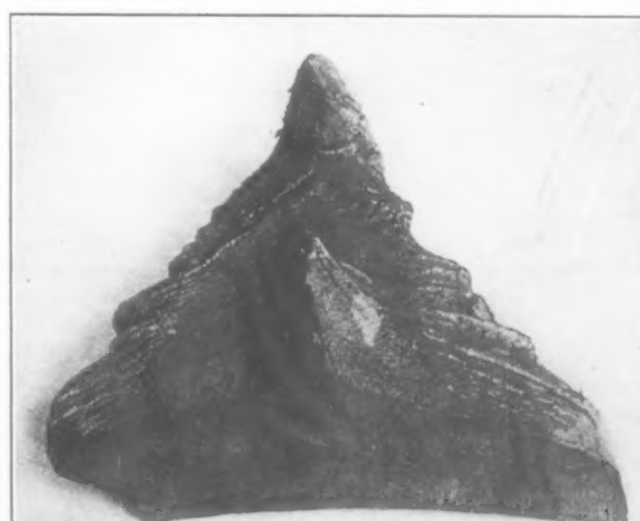


FIG. 19 PIECE OF STEEL TIRE BROKEN IN A DROP TEST

point. (See Fig. 14.) This condition should induce the metallurgist to pay more attention to the causes which produce strain-

ing in other words, to the tensions which may exist in the pieces after being cast or forged. This is illustrated by the changes in brittleness which occur in glass undergoing heat treatment. The heat treatment does not bring about any change in its molecular arrangement, but the glass coming out of the furnace is very brittle, and after being properly annealed is so much less so that it is in the so-called unbreakable state; that is to say, it can sustain shocks and bending to a much greater extent than ordinary glass.

The first condition is one of very uneven tension; the second, one without tension; and the third, one which has a beneficial tension.

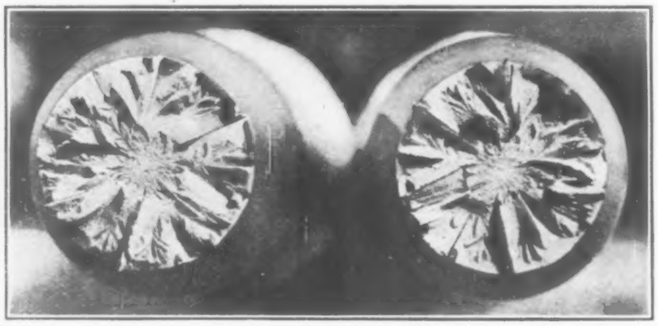


Fig. 20 Test Piece Ruptured under Tension: Fracture Originated Along the Axis

This unevenness of tension also exists in steel, irrespective of the chemical or other changes in structure. An example of the effect of these internal tensions is given by Fig. 21, which shows a fracture in a rail. It is evident that the fracture was started in the neighborhood of the neutral axis, a fact which could not be accounted for if the piece had been under normal conditions;

Fig. 21 Tension Fracture in a Steel Rail

therefore the causes of a fracture of that kind must be traced to a tension most likely produced in the rolling mill. This case illustrates the mode of cutting which produces bright surfaces in glass, and which can only be explained by the presence of a vibratory motion of the surfaces when they are apart from one another.

In conclusion the author trusts he has created the impression that a methodical study of fractures is of the greatest importance, especially as it leads to a knowledge of the causes of failures which cannot always be attributed to the intrinsic qualities of the metal itself.

Large Gas-Well Fire Extinguished with Explosives

The successful application of explosives in extinguishing a fire at one of the Standard Oil Co.'s wells near Taft, Cal., reported in a recent issue of the *American Gas Engineering Journal*, suggests the possibility of greatly simplifying the present expensive methods of extinguishing gas-well fires, oil-well fires and oil-reservoir fires.

Drilling operations with a rotary drill were in progress in well No. 7, in the Elk Hills, in the Midway Oil Fields. The well was at a depth of 2135 ft. in 10-in. casing when a supposed water sand was encountered. To test this sand for water the mud in the well was bailed down to relieve pressure and to allow any water present to accumulate in the well. During the course of bailing the well blew out under tremendous pressure and gas began to flow at the rate of 125,000 cu. ft. per min.. An attempt was made to get the well under control by closing a 12½-in. gate valve with which the casing was equipped, but the shale and sand carried by the stream cut out the seat of the valve while the gate was being closed and the well continued to blow. Soon afterward the friction caused by shale and sand had produced a red-hot heat on the casing, and the gas, igniting, burst into a column of fire, gushing 300 ft. skyward. Its maximum width of about 50 ft. was reached after the flame had traveled about 100 ft. upward. The gas emerged from the casing with such force that for a distance of 12 ft. about the casing there was no flame. The derrick, 100 ft. in height, was immediately consumed and all that remained was a twisted mass of iron and steel. Metal at the casing melted, while within a radius of 50 ft. it was raised to a white heat. Everything within hundreds of feet was burned and baked. It is reported that the fire could be seen from a distance of 80 miles and that the roar from the escaping gas could be heard at a distance of ten miles.

Attempts were made to extinguish the fire, first with ten boilers, and subsequently with sixteen and twenty boilers. With the twenty boilers there were twenty-one 3-in. lines and nine 4-in. lines and eleven rotary pumps throwing steam, water, mud and carbon tetrachloride. Nearly half a million dollars were expended in vain attempts to extinguish the fire. In the meantime the casing above ground had blown off, the well had formed a crater and the flame was down to the ground level.

As a last resource it was decided to suspend a package of Giant blasting gelatin upon cables in such a manner that the package could be safely brought to and exploded at the edge of the fire at a distance of about 40 ft. above the ground. Two derricks approximately 40 ft. high were built on either side of the burning well and so far away that the heat would not destroy them. A 9/16-in. steel cable was attached to the top of one of them, then laid around the well outside of the heat zone to the other derrick where it was run through a pulley at the top and the end attached to the drum of a small winding engine underneath. The explosives, bound in one package and covered with heavy sheetings of asbestos, were securely attached to this cable at the same distance away from the first derrick as the burning well was. The engine under the second derrick began drawing the cable taut, which pulled the explosives toward the well and at the same time hoisted them. When they had reached the proper spot they were exploded electrically. All of these operations had to be done very quickly so as to bring the explosive charges to the necessary point before they were ignited or exploded by the heat from the burning well.

When the package exploded the fire was divided into three sections. The section at the point of explosion was moved bodily away from the column of gas in a horizontal direction, the upper section was blown upward and beyond danger of re-ignition of the gas column, while the lower section was snuffed out, the flow of gas being temporarily checked.

An idea of the enormous amount of gas flowing from this well may be formed by noting that it could conveniently supply eight cities of the size of San Francisco, which alone consumes 22,000,000 cu. ft. of gas each day.

Physical Basis of Air-Propeller Design

By F. W. Caldwell[1] and E. N. Fales,[1] Dayton, Ohio

Description of wind tunnel at McCook Field, Dayton, Ohio; phenomena discovered by its use; analysis of propeller theory and application thereof to fan design in the light of facts established experimentally; methods for visualizing air flow.

The wind tunnel at McCook Field is notable first for the high velocity of air used (500 m.p.h.) and second, for means adopted to visualize the air flow. This latter is done by maintaining the humidity of the air in the tunnel at a certain predetermined level and by providing opportunities for its condensation where it will show the character of the air flow.

The study of air flow by these means gave new data on vortex formation created by the presence of aerofoils and made it possible to form a clearer conception of the conditions surrounding the operation of propellers.

The value of such investigations as can be made with the McCook Field equipment lies in the fact that hitherto the theory underlying flight phenomena has been purely rational and not directly applicable to engineering design because of the absence of empirical measurement of flight vortices. Because of this, it was impossible to predetermine the performance of aerofoils of new shapes, speeds and sizes without first building a model and determining the particular coefficients applicable to the new design experimentally. Data obtainable in a wind tunnel having provision for visualizing the air flow are, however, capable of supplying this deficiency.

The authors show the application of some of the data obtained to the design of blowers and fans.

Members of The American Society of Mechanical Engineers as well as most of the older engineering professions have shown a keen interest in aeronautical problems and in the progress of the scientific side of aviation. This interest is no doubt partly due to the romance of seeing realized mankind's age-long desire to imitate the birds in their flight; and partly to the patriotic hope that America will become predominant in a field which owes its existence to two American inventors.

This interest is very valuable to aeronautical engineers, as we feel that association with the older professions ought to enable us to keep at least one foot on the ground. At the same time it is felt that the information gained in aeronautical research may prove helpful in some ways to the mechanical engineers.

It is the purpose of this paper to summarize our conceptions of flight phenomena as developed by the use of the high-speed wind tunnel at McCook Field. The understanding of the fundamental aerodynamical phenomena upon which flight depends has been rather vague throughout the past, simply because of the invisibility of the air. Our knowledge of these phenomena has been based on deductions made from observing the forces produced. (The variation of the air resistance has been well understood for various types of wings, and also for solid bodies of geometrical shape.) To evaluate these forces, however, the results only have been analyzed—not the phenomena themselves. Measurement of the dynamic and static pressures in a given air flow has contributed somewhat to our knowledge of what goes on in the air. The use of threads, solid particles, such as smoke, etc., has also been universal for determining the direction of given portions of an air flow. Such methods, however, have barely scratched the surface of the problem and have been of small value to the aerodynamical analysis of the mathematicians.

A means of actually visualizing the air is therefore of greatest interest; and while its immediate application has been to the specific case of studying air flow past aerofoils, many other uses suggest themselves wherever air in motion constitutes an engineering or scientific factor. Thus, for instance, the study of meteorology involves a knowledge of the circulation of air currents on a large scale over the earth's surface; this knowledge, too, is imperfect because of the invisibility of the medium concerned, and can be greatly improved by application of means for visualization. Moreover, the flow of air in ventilation and other engineering processes is a question which may frequently require analysis by a method of visualization.

It is thought that the general engineering profession will quickly deduce from the experiments recorded in this paper principles which can be of service in their more commercial fields. Therefore it has been our aim to summarize the main features of these experiments without going too deeply into the technical details necessarily of interest only to the aeronautical engineer.

The experiments have resulted in discoveries which may be briefly summarized as follows:

The flow of air, whether in a duct or past an aerodynamic body, is subject to parasite energy losses connected with accidental whirls and eddies, and also to internal motion on account either of

Fig. 1 Photo of Tip Vortex, Camera Axis being Coincident with Vortex Axis

the shape of the containing duct or the aeronautical body. Analysis of these motions in the air can be facilitated by visualizing them. The writers' method for producing visualization involves condensation of the moisture contained in the air. This moisture, when turned into visible vapor by suitable means, takes up shapes dependent upon the motion and pressure gradient of the air and justifies us in considering that the air itself is thus visible. (See Fig. 1).

When the air is made to flow past an aerodynamic body, special shapes of flow result and can be visualized by our method. It has been shown in our experiments that when the speed changes, the characteristics of the internal motion in the air alter. This alteration has been a source of much uncertainty to aeronautical engineers in the past; but the combination of visual study of these changes of air flow, together with quantitative analysis of the forces involved, has made it possible to throw much light on the underlying structure of the air as it applies to dynamic flight and propulsion.

In our experiments, then, we introduced small wooden wings (aerofoils) into the air current of the wind tunnel and studied their performance; intending to interpret the results for the purpose of propeller design.

Wind-Tunnel Apparatus Used for Observing Aerofoil Coefficients and Air Flow

The McCook Field wind tunnel (Fig. 2) was designed by the writers for advanced study of aerofoil coefficients used in propel-

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Abstract of paper to be presented at the Spring Meeting, St. Louis, May 24 to 27, 1920, of The American Society of Mechanical Engineers. Advance copies of the complete paper may be obtained gratis on application. All papers are subject to revision.

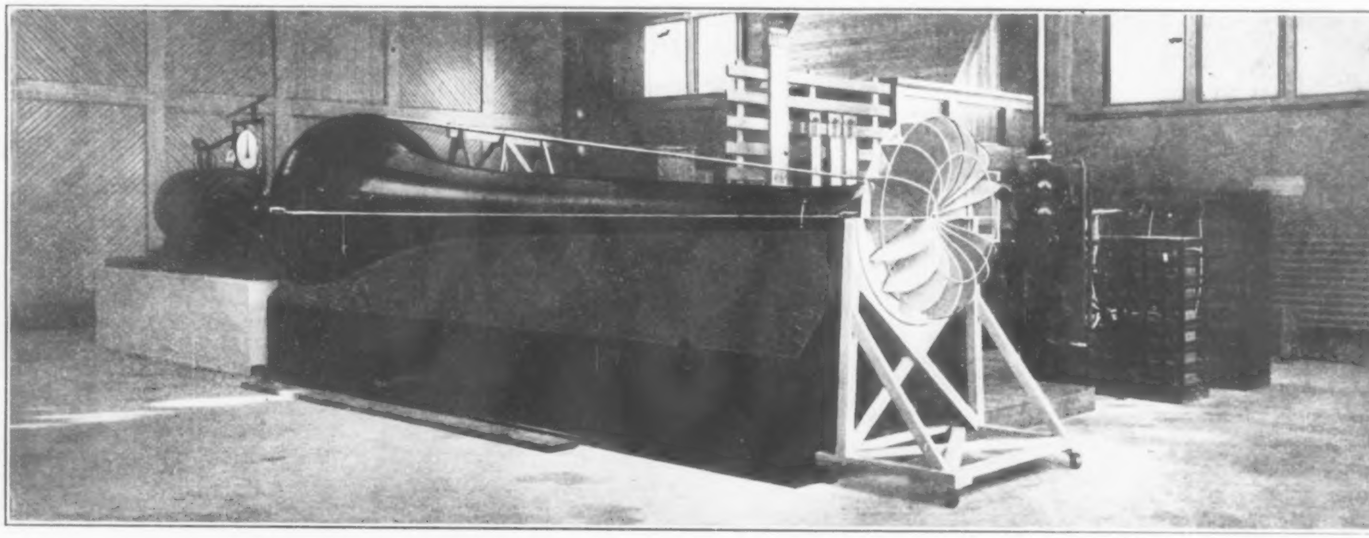


Fig. 2 McCook Field Wind Tunnel, General External View

lers. It is a departure from the accepted type of wind tunnel in two ways: first, it has a speed higher than elsewhere attained for similar purposes—500 miles per hour at 200 hp.; second, it makes possible the visualization of aerodynamic phenomena.

It seems wise to summarize briefly the general function of a wind tunnel, which is the laboratory apparatus of the aeronautical engineer. An airplane, when once in the air, is very difficult to analyze; neither the pilot nor an observer on the ground is able to gage accurately the speed, angular attitude, nor the air forces acting. So far, no thoroughly accurate instruments for accomplishing full-flight analysis have been perfected. Projects have been proposed for attaching a full-sized airplane to a moving electric locomotive properly equipped to record accurately all the forces produced; but such a plan has drawbacks. It is found that the best, most accurate and cheapest way to analyze airplane characteristics is by means of the wind tunnel. This is a confined artificial blast of air which is made to blow against a model wing or airplane. The model is supported in the air blast by a thin rod reaching into the wind tunnel from outside, where it connects to a delicate scale. Thus all forces created on the model are transmitted to the scale where they can be measured.

It is found that the forces due to the air current blowing against fixed objects are the same as though the object were moved through still air, provided the air current is smooth and without eddies. Elimination of eddies is therefore an important requirement in a wind tunnel.

The forces found in a wind tunnel apply to full-sized machines, and wherever aeronautical design is carried on the wind tunnel is essential. Besides the McCook Field wind tunnel there are in America about a dozen others. In Europe there are many more, the British National Physical Laboratory employing seven. The largest in existence is now being built at Paris, 13 ft. in diameter and of 1000 hp. capacity. The typical wind tunnel has a stream of air 15 to 50 sq. ft. in cross-sectional area, flowing at a velocity of from 30 to 90 miles per hour.

The Question of Wind-Tunnel Speed

The speed and size of a wind tunnel have a recognized importance in the interpretation of the results obtained. The usual coefficients of aeronautical engineering are determined by tests on a model aerofoil of from 3 to 6 in. chord at velocities of 45 to 130 ft. per sec. The data obtained must be applied in the full scale of areas a hundredfold greater in the case of wings, and to velocities ten times greater in the case of propellers. There may be a discrepancy between model and full-scale coefficients, and this is spoken of as "scaling effect."

Scaling Effect. While scaling rules and empirical factors worked out in practice have enabled us to produce very fair results, there is decided room for improvement. Indeed, so meager is the available information on the scaling effect, as treated under the "law of dynamic similarity," that a growing tendency has appeared among aeronautical engineers to regard

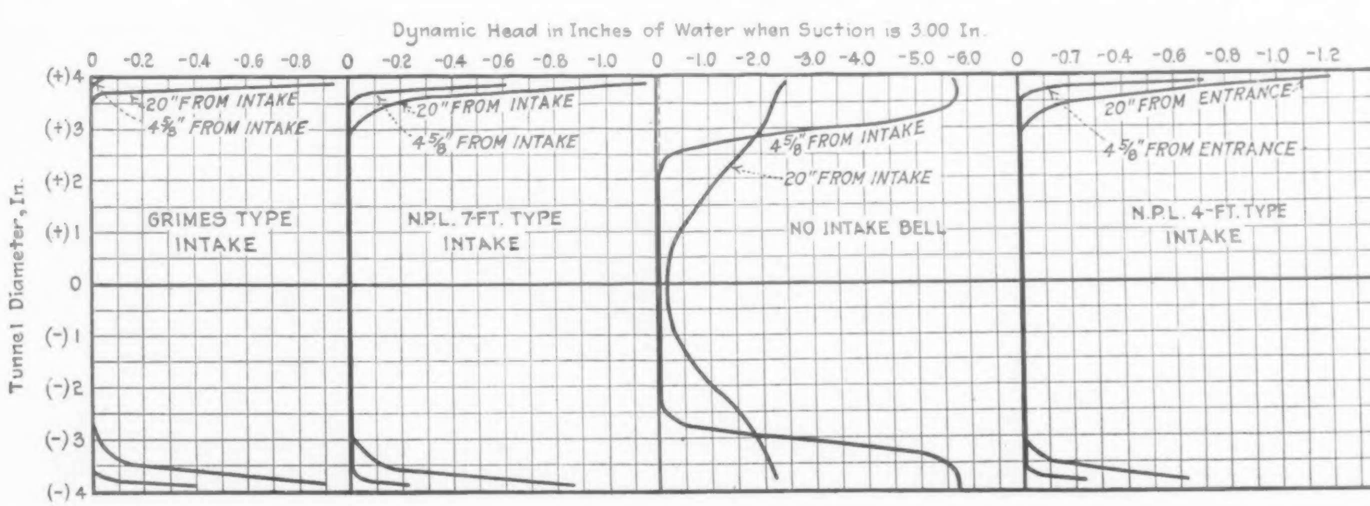


Fig. 3 Chart of Velocity Traverses for Various Intakes

the classical coefficients K_x (coefficient of drag) and K_y (coefficient of lift) as inadequate.

It has been almost universally the practice to write

$$L = \rho/gK_yAV^2$$
$$D = \rho/gK_xAV^2$$

where L is the lift (vertical lifting force), D the drag (resistance), A the area of the supporting surface, V the velocity of advance, ρ the density of the air in weight units, g the acceleration due to gravity, and hence (ρ/g) the density of the air.

It is well known as the result of experience that the values of K_x and K_y vary somewhat with velocity and also with the size of the surface under consideration. If l represents one of the linear dimensions of the surface and ν the coefficient of kinematic viscosity, it is assumed, according to the law of dynamic similarity, that values of K_x and K_y are functions of Vl/ν. Since ν is usually considered constant, it is customary to compare the product Vl for experiments in a given medium.

The wind tunnel designed by the writers permits the attainment of a Vl product of 60 (V in ft. per sec., l in ft.). While this figure is twenty times less than the corresponding full-sized wing values, it is only four to eight times less than full-sized propeller values.

As a matter of interest, tip speeds of some of the propellers in actual use are given below:

Airplane	Engine	M.p.h.
USD-9	Liberty-12	650
VE-7	Hispano-Suiza, 150 hp	545
Thomas-Morse	Le Rhone, 80 hp	380
Verville Chasse	Hispano-Suiza, 300 hp	600
Roché XB-1-A	Hispano-Suiza, 300 hp	625
Curtiss JN-4	Curtiss OX-5	420
DH-9	Rolls-Royce, 375 hp	430

It would be ideal if a wind tunnel could be built large enough for testing propellers and airplanes of full size and speed. Such apparatus would, of course, be enormous and of prohibitive cost. We must therefore be content with wind tunnels whose Vl product is smaller than the full-flight value. In designing a tunnel

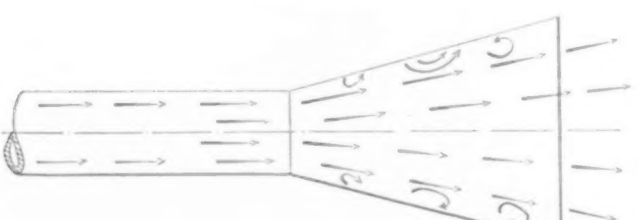


Fig. 4 Diagram Showing Eddies in Cone of Too Large Angle

we may have either large size and low speed, or vice versa. In general a large wind tunnel requires a large, expensive hall, while a high-speed tunnel requires high horsepower.

Thus in the McCook wind tunnel we have attained a velocity equal to full-flight values, and the size of model is correspondingly small. The results obtained, however, demonstrate greater significance than were the same Vl product obtained with a larger model and smaller velocity. By means of the high velocity, discoveries of outstanding importance have been made, namely, the means of visualizing flight vortices, and the identification of changes in these vortices with simultaneous changes in the aerofoil coefficients.

Description of the McCook Field Wind Tunnel

The tunnel has the form of a venturi tube $18\frac{2}{3}$ ft. long, built of turned laminated wood. Its proportions and novel features have been the subject of exhaustive investigation and experiments on scale models.

Intake Bell. Thus the intake bell has a radius of curvature of $1\frac{5}{8}$ times the throat diameter, such as best to take care of the *vena contracta* and insure best velocity distribution and parallelism in the air flow (see chart, Fig. 3).

Throat. The throat is unusually short—1.3 diameters—with resulting economy of power. The short throat and the location of the model close to the intake are justified by the study of the chart in Fig. 3, and are made possible by the elimination of the usual "honeycomb" and by proper intake-bell design.

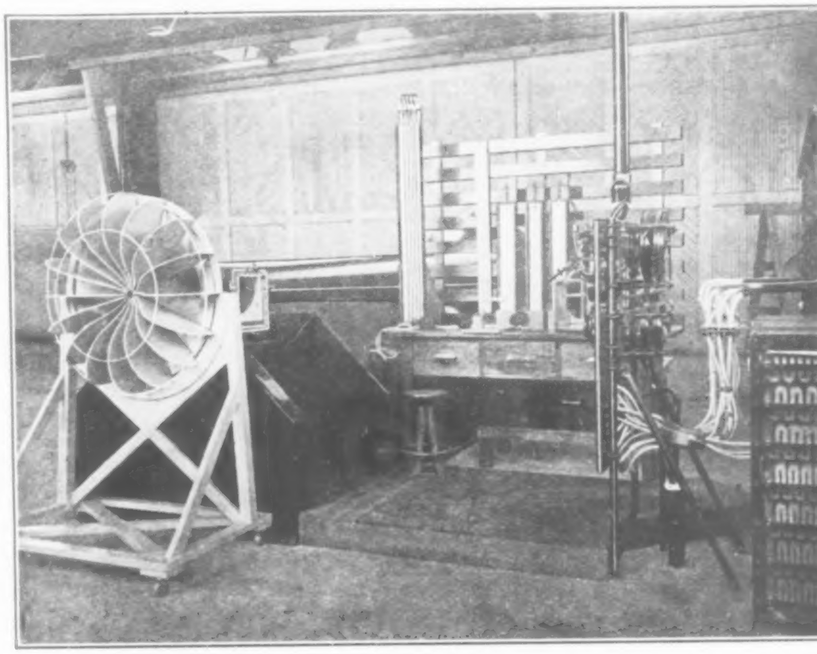


Fig. 5 McCook Field Wind Tunnel, Showing Operating Panels

Expanding Cone. The cone leading from throat to fan has an angle of 7 deg., the maximum value established by Eiffel. We have found that in cones of larger divergence the air flow does not fill the cone, a space of whirling and eddying air being left between the blast and the containing walls (see Fig. 4), with resultant loss of energy. The principle involved is that flowing air surrounded by solid walls loses less energy by surface friction than if surrounded by inert air.

Straighteners. To eliminate velocity fluctuations a novel straightener is used—the conventional "honeycomb" being eliminated. The straightener is placed 4 ft. down the cone and has four radial blades 4 ft. long, so located as to prevent inflow whirl by obstructing the formation of the pressure apex. An auxiliary straightener (Fig. 5) with flat radial vanes is located outside the intake; and together the two reduce velocity fluctuations from 15 per cent to 3 per cent, without appreciable power loss.

Power Plant and Fan Measurements

Velocity is measured in terms of dynamic head minus static head. For measuring dynamic head there is an "impact" tube at the throat somewhat off the center of the tunnel axis. For measuring static head a perforated plate is used, set in flush with the walls. A differential manometer records the velocity head, the whole apparatus being analogous to the conventional pitot tube and Krell manometer.

Temperature of the air passing through the throat is calculated on the assumption that expansion is adiabatic from atmospheric pressure to pressure corresponding to condensation, and is polytropic below the latter pressure. Correct knowledge of throat temperature is, of course, essential, and it is necessary to develop a special method of themometry for reading it. Present methods are inapplicable to its direct measurement, for a thermometer introduced into the air stream occasions more or less adiabatic compression of the air striking it, with consequent rise

of temperature at the point of impact. (See chart, Fig. 6.) The most advantageous position for the thermometer is with the bulb down stream, where it is subject chiefly to skin friction rather than impact. Further investigations are being made of the matter.

The balances are of two types. The first one measures lift and drag on two separate instantaneous reading Toledo scales

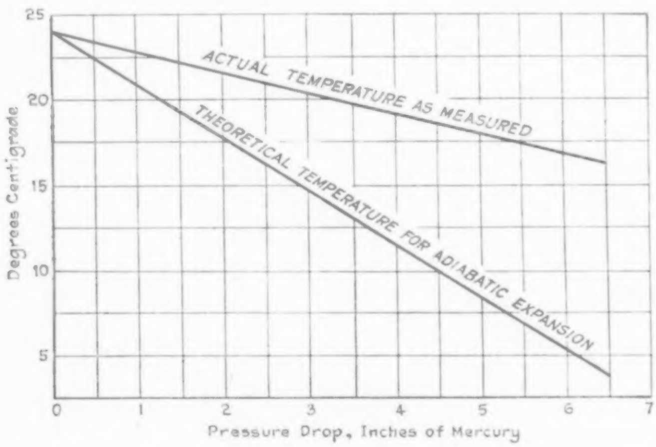


Fig. 6 Chart of Theoretical and Measured Temperatures

and is mounted upon a portable carriage (see Fig. 7). The spindle for the model projects horizontally and axially from this carriage into the mouth of the wind tunnel, carrying the model at its free end. The spindle terminates in a thin flat bar, the latter clamping a graduated disk which is rigid with the model at the center of the span. Three advantages of this type of balance are: (1) That instantaneous readings make it possible to synchronize balance and velocity observations and to practically eliminate the effect of velocity fluctuations; (2) The air forces can be qualitatively studied; as, for instance, in the case where a given setup has two values of K_y or K_x. The balance can then be seen to change from one reading to another; (3) The method of support affords a highly accurate means of skin-friction observation.

The conventional supporting spindle, as adopted at the National Physical Laboratory, cannot be utilized under the conditions of these tests. In order to definitely delimit the effect of the supporting member, further developments are proposed where this effect will virtually be eliminated from the tests. The effect of the center support on the lift coefficient is not considered serious. This conclusion is based on experiments run at other laboratories where the effect of the support has been determined; also on a comparison of the present series of experiments with tests made elsewhere on a larger model supported at the end, for the same Vl values. The effect of the center support on drag, however, is known to be large; the air-flow disturbance is visualized in Fig. 8, where it appears as a white tuft above the support.

Power Plant. The power plant consists of a Sprague dynamometer, capable of delivering 200 hp. for one-half hour at 250 volts and 1770 r.p.m. without overheating. The 5-ft. fan (Fig. 9) is made with a solid-center disk 40 in. in diameter, and has 24 blades 10 in. long. At the upstream side of the 40-in. disk a bell of equal diameter is fixed in the tunnel so that the air is let up to the annular discharge opening with a minimum of eddies. The operating efficiency of the whole tunnel is 75 per cent higher than has been usual for the determination of aerofoil coefficients in other wind tunnels. By efficiency is understood the ratio of kinetic energy of air stream at throat of tunnel, minus the energy absorbed by the fan, all divided by the energy of the air stream at the throat.

Careful study of fan and cone design results not only in reduced losses but also in reduced noise. The question of noise has in the past been a serious objection to speeds greater than 70 miles per hour in wind tunnels. The roar of the fan is analogous to that of an airplane propeller, which usually makes more noise than does the unmuffled motor exhaust. For wind-tunnel use the combination of fan and cone adopted has brought about a considerable improvement, as indicated in the following tabulation:

From the operator's position:	Fan is noiseless at......	50 m.p.h.
	Starts to roar at.........	60 m.p.h.
	Conversation easy at....	125 m.p.h.
	Conversation slightly forced at	155 m.p.h.
	Possible 12 in. apart at.	240 m.p.h.
	Possible 4 in. apart at..	300 m.p.h.

Fan. The fan represents a very interesting union of airplane-propeller principles and blower-design principles, combining the high pressure usually associated with centrifugal blowers with the high efficiency of the airplane propeller. While essentially a propeller fan of aeronautical design, its 16-in. pressure head is such as would ordinarily be expected only from a centrifugal blower.

This application of airplane-propeller principles to blower design is significant to the ventilation engineer, who may by such means produce in wood, at comparatively small cost, blowing apparatus of high efficiency, high horsepower, high head, and reduced noise.

Application of Propeller Design to Commercial Use

As a further illustration of the benefits to the ventilation engineer of airplane-propeller principles, the following may be cited as of interest:

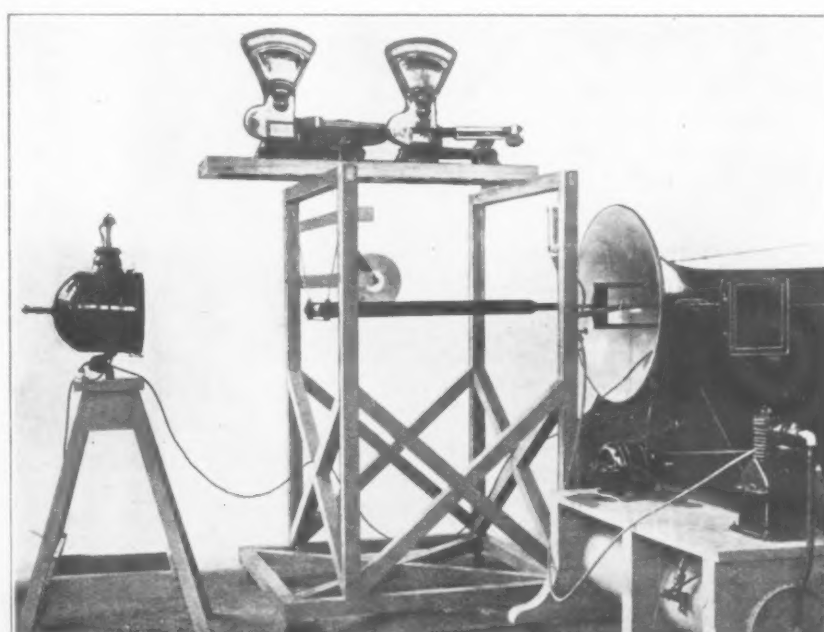


Fig. 7 McCook Field Wind Tunnel, Balances and Intake

It has been found possible, by impressing special properties, to extend the usefulness of one of our most common and universal devices—the electric cooling fan. In the ordinary electric cooling fan referred to, the air flow is analogous to that of an airplane propeller rotating at a fixed point on the ground, and is shown in the sketch, Fig. 10-*A*.

The blast converges as it leaves the blades, reaching a maximum velocity a short distance from the fan, and gradually dis-

sipating its energy as the flow lines expand along a small-angle cone. Thus, in such a blast the energy is concentrated in a narrow stream. Numerous experimenters have conceived the idea of placing vanes in front of these fans to diffuse the air and make it spread outward, but no practical success has been secured.

The problem is one of many minor ones which have found their solution as a side issue to the war activities of the Air Service. By judicious application of aerodynamic principles, a cooling fan has been developed which delivers a fan-shaped expanding blast, while moving as much air as the older conventional type of fan. See sketch, Fig. 10-*B*.

This fan directs its stream, not along a single axial line, but along a sector embracing 90 or even 180 deg. The advantages are obvious:

First, the energy of the blast is rapidly dissipated over a large area, causing a large, gentle circulation in place of a small, violent one.

Second, the blast spreads over an angle equal to that attained by the conventional oscillating type of fan, and accomplishes the same beneficial results without the unpleasant features associated with intermittent action.

Third, such a fan can produce a truly conical blast of which the fan-shaped expanding blast is only a special case; thus, the advantage of large cross-sectional area is secured from a small high-speed fan; and for purposes of overhead or ceiling use such a device is considerably cheaper than the conventional low-speed, large-diameter ceiling fan.

Fourth, the device involves only a simple, inexpensive addition to the conventional fan, may be readily applied to it, and causes no additional noise.

Visualization of Flight Vortices by the Writers' Method

The method of visualizing air flow discovered by the writers together with C. P. Grimes offers a solution of the fundamental problems of aerodynamics. This problem is the quantitative empirical measurement of the phenomena of fluid dynamics as applied to flight and air flow.

The accepted theory upon which flight has its physical basis is purely rational. It has not yet been directly applicable to engineering design, because empirical measurement of flight vortices has never been made. Therefore, the aeronautical engineer's

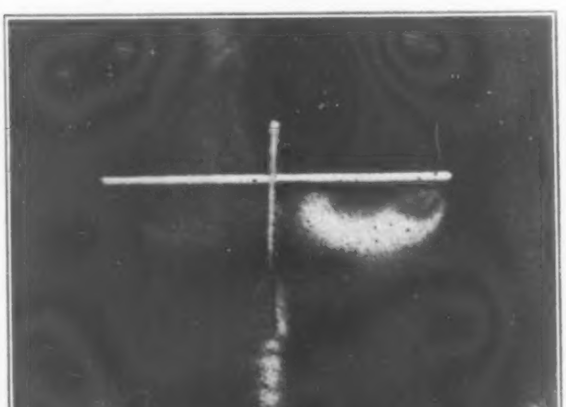


Fig. 8 Tip Vortex, High-Lift Régime

use of aerodynamics is largely according to the cut-and-try method. He cannot, on the drafting board, depart from known shapes, speeds or sizes without first building a model and determining the coefficients applicable to his new design.

To illustrate this point it is only necessary to refer to the simplest case, that of an airplane wing. We can measure the coefficient of force on a small model of this wing to an accuracy of 1 per cent. But we do not know definitely how the accuracy is changed by scaling up to full size, or to full speed. We cannot, without tests, predict the change of coefficient to be expected when the wing shape is altered, or the angle of attack, or the position with reference to other surfaces.

Aerodynamical theory will serve practical use when supported by empirical data. In the past, flight vortices have never been

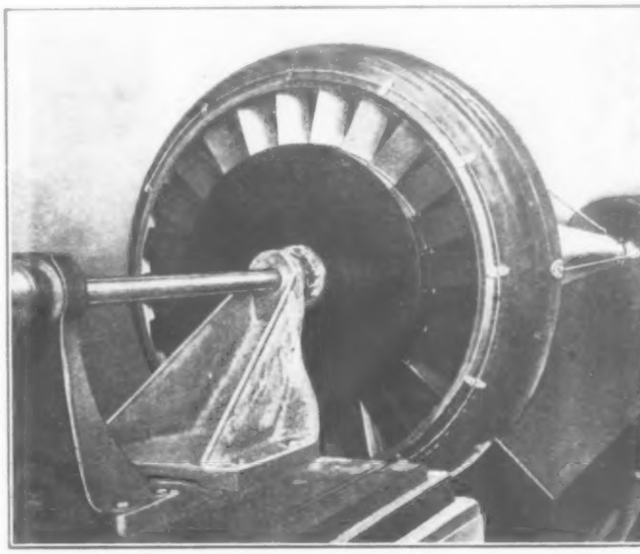


Fig. 9 McCook Field Wind Tunnel, Fan End

measured, nor even visualized to a usable extent. Analysis of air flow has been confined to the use of smoke or powder set loose in the air to indicate lines of flow; or of threads used as wind vanes. Or we have been driven to analogies derived from study of fluids of different viscosities and densities, such as water. Or, further, we have sought by measurement of static pressures in the air surrounding a body to deduce the lines of flow. But these methods have given small encouragement to the practical application of the vortex theory to engineering use.

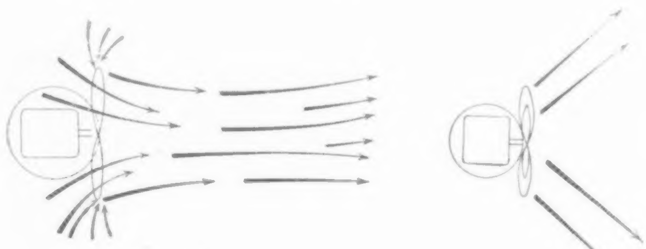
The writers' method bids fair to supply the missing link between aerodynamical theory and design. It depends upon the fact that the moisture in the air condenses out as fog when the temperature is reduced to the dewpoint, provided there is a solid or liquid nucleus to start the condensation. In the McCook Field wind tunnel the temperature drop is brought about through expansion of the air during acceleration due to 100 in. of water suction. Relative humidity of the atmosphere can be artificially raised if too low. The necessary nucleus for condensation is provided by the model itself.

Flight vortices become readily visible by the writers' method and can be photographed with the aid of searchlights. Several efforts were made to take the pictures with a plate camera but these were not very successful. Finally a good moving picture was taken and some of the films enlarged. While these films showed up very well on the screen the detail was not very clear in enlargement, so that, in addition to the searchlights which were provided with nitrogen-filled incandescent lamps, two carbon arc lights were set up in order to give a greater amount of blue light. The results obtained from the motion-picture camera with the carbon-arc lighting were fairly satisfactory, and a number of enlargements from the motion-picture films are reproduced in this paper. Fig. 1 is an enlargement of a moving-picture film looking downstream, and shows the left half-span of a small model aerofoil, with tip vortex trailing downstream from the tip and edge vortex-sheet below the model. The edge vortex-sheet is made up of vortices with axes parallel to the rear edge of the model; they build up and run off at such frequency as to appear continuous. It is somewhat inferior to visual observation. To the naked eye the tip vortices are in line with the wing tips

and are clean-cut, perfect circles. They extend downstream a distance of several dozen chord lengths from the rear corner of each wing tip, enlarging in diameter as the distance increases, and converging slightly in the horizontal plane (see Fig. 11). In the vertical plane the tip-vortex axis takes a decided downward angle, intermediate between the horizontal and the line of the flat sheet of edge vortices.[1]

At slow speeds condensation is not obtainable, but the vortex phenomena can be corroborated by injecting a jet of visible steam into the air current. Such a jet, when of proper saturation, affords a better indication of flow direction than does smoke or thread.

Adequate analysis of the flight vortices is now being made with stroboscopic apparatus. The shape, size and direction of the



A B

Fig. 10A Air Flow through Typical Electric Fan
Fig. 10B Air Flow through Modified Electric Fan

tip vortices can be easily noted and seem fairly susceptible of measurement. The periodic run of the edge vortices is too quick for recognition by the naked eye, or even for identification by the moving-picture camera; it requires stroboscopic analysis.

The observed vortices differ for different aerofoil setups and different speeds. For instance, the observed tip vortex at 18 deg.

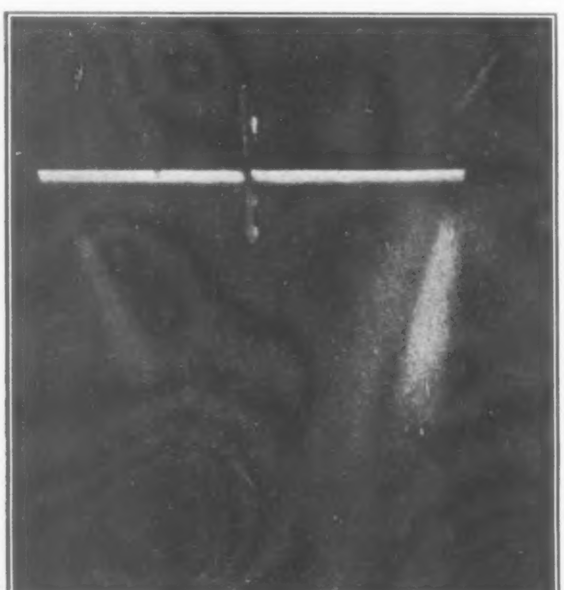


Fig. 11 Plan View of Flight Vortices

has less than one-half the diameter manifest at 8 deg., while the line of edge vortices is less noticeable at 18 deg.

Again, the character of the general vortex phenomenon undergoes remarkable change at the critical speed. In the high-lift régime the general shape is like a trough whose floor (edge vortex-sheet) slopes downward from the trailing edge, and whose walls (tip vortices) are increasingly high as the distance downstream increases. The cross-section is roughly like a shallow U.

At higher speeds, however, in the low-lift régime, the observed phenomenon is suddenly altered. Following out the above homely analogy, we may imagine that the "walls" of the trough remain substantially as before. The "floor," however, splits longitudinally, curls upward, and extends the two limbs, now free, to a point well above the level of the tip vortices. This is shown

A

B

Fig. 12 Diagram of High- and Low-Lift Vortices

in enlargements of two motion-picture exposures which were intended to record the sequence of the change. These photographs, however, were not altogether satisfactory, and are therefore replaced by the two sketches of Fig. 12.

Fig. 12-*A* is a diagram of the end view of the high-lift phenomenon as it appears distinctly to the naked eye. The right-hand side of the aerofoil in Fig. 8 approximates this condition, the left-hand side having already gone over to low-lift flow. Fig. 12-*B* is a diagram of the low-lift phenomenon; the left-hand side of the aerofoil shows this fairly well, the right-hand side being in transition stage. Fig. 11 is a three-fourths view of the low-lift flow, and also represents other features mentioned above.

An interesting variation of the flight vortices is furnished by replacing the aerofoil by a flat disk normal to the wind. Here the phenomenon can be seen as a "stream-line" fog surface, converging towards a point half a dozen diameters downstream.

Fig. 8 illustrates the distance above the aerofoil to which the flight-vortex phenomena may extend, and shows their tendency to merge with other whirls attributable to the wind-tunnel walls. The extent of the phenomenon may be four or more chord lengths above the aerofoil; this further develops a discovery made by the writers in 1911, when it was shown experimentally that the air flow above a wing is disturbed to a distance of at least four chord lengths.[1]

Visualization of Unobstructed Air Flow

When the model is removed the vortices and eddies of flow through the unobstructed throat may be observed by looking into the intake or through the transparent shield of the observation section. The condensation is more pronounced behind the impact tube and thermometer bulb than elsewhere, since these are obstacles to the flow and therefore constitute nuclei for condensation. A projecting cotter pin $\frac{1}{16}$ in. high at the wall causes a perfect vortex, which shows up against the white, foggy background as a black circle.

The general appearance of the air flow, which may be considered typical of all air flow, is as follows: A cross-section at the throat shows a seething mass of fog specters, denser at the

[1] For an excellent mathematical discussion of the shape and arrangement of the tip vortices and the trailing vortices, see report No. 28 of the National Advisory Committee for Aeronautics (U. S.). On page 44 the author, Dr. George de Bothézat, has shown in an interesting way that the axis of the tip vortices is intermediate between the direction of movement and the sheet of trailing edge vortices.

[1] See The Center of Pressure Travel on Airplane Surfaces and Birds' Wings, Mass. Inst. of Technology, 1911. Reference may also be made in this connection to the work of J. R. Pannell, dealing with experimental evidence as to the extent of circulation about an aerofoil.

wall than at the center, though occasionally the entire disk fills up with fog to the point of opaqueness. The specters have in the cross-sectional plane a gentle movement like the flame of an alcohol stove, showing the constant readjustment of equilibrium. Vortices and S-shaped whirls continually form and, after moving about, lose themselves in the general confusion. In a diagonal view they take the appearance of long, foggy fibers, stretching down the tunnel like wooden moldings. The axes of whirl, of course, are longitudinal. Under proper humidity and lighting conditions the whole becomes a beautiful iridescent sight, violet and purple hues predominating.

Lift Coefficients. Coefficients of lifting force and resistance have been determined for a series of model aerofoils 6 in. long, 1 in. in chord length, camber varying from 0.08 to 0.20. The cross-sectional shape is that upon which the Engineering Division has standardized for propeller use. A chart of lift coefficients for one of these aerofoils (0.12 camber) is presented, and shows the variation of lift coefficient over the entire range of speeds and angles tested. See Fig. 13.

The outstanding conclusion to be drawn from the tests is that we have more than one régime of air flow to deal with in aerofoil study, and that these régimes are separated by conditions of discontinuity. The characteristics usually associated in aeronautical engineering with a practical aerofoil do not apply outside the small range of cambers, speeds and angles utilized in flight. Beyond this range the flow about the aerofoil no longer produces the familiar results in terms of lift and drag but becomes analogous to the flow about a body of irregular shape. Efficient lift of an aerofoil is only a single case of several distinct aerodynamic phenomena resulting from air flow past a solid body. When the speed of air flowing past an aerofoil increases, there is first a régime of relatively low-lift effect, then at higher speeds an efficient lift effect such as applies in flight, then at still higher speeds a drop back to a second low-lift effect. As the angle of camber increases, the high-lift régime becomes discontinuous and is succeeded by the low-lift régime; the transition point is spoken of in conventional graphs as the critical, or stalling angle, or the "burble point."

All of the sections show, at certain angles, two speeds at which the flow is unstable and discontinuous. At the point of discontinuity occurring at the lower speed, increase of speed shows an increased lift coefficient and a decreased drag coefficient so that the lift-drag ratio (L/D) is enormously increased. At the point of discontinuity occurring at the higher speed, increase of speed shows a decreased lift coefficient and an increased drag coefficient, so that the lift-drag ratio is enormously decreased. Thus these sections have a definite speed range, at each angle, within which the flow is efficient and produces a high lift-drag ratio, and a fairly constant lift coefficient. It may be called the régime of high L/D, and includes the phenomena appertaining to practical flight. This speed range has been definitely measured for the higher angles, but apparently it goes beyond the speed obtainable in the tunnel for the lower angles.

It will be noted that the K_y curves are drawn discontinuous to correspond with discontinuity in the type of air flow. In some cases the graphs show a third curve intermediate between the high-régime curve and the low-régime curve. This third inter-

(*Continued on page 260*)

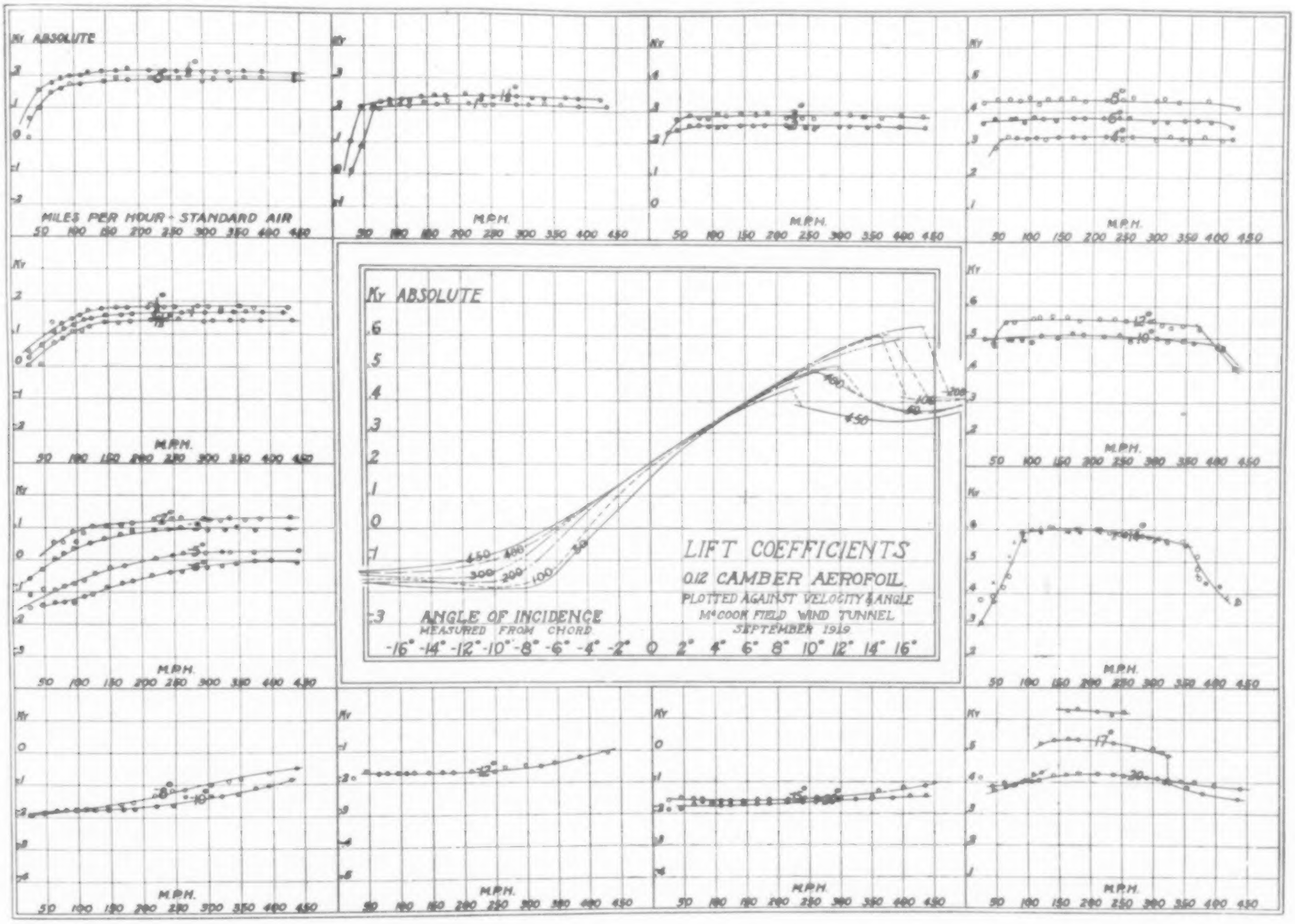


Fig. 13 Chart of Lift Coefficients of 0.12 Camber Aerofoil

Simplification of Venturi-Meter Calculations

By GLENN B. WARREN,[1] SCHENECTADY, N. Y.

In this paper the author describes a method which he has devised for the simplification of the calculations involved in the venturi-meter measurement of the flow of compressed air, and which reduces the work of one determination to a simple slide-rule computation requiring but a few settings. The method, which is described in considerable detail, is based on the venturi-meter formula as given by Herbert B. Reynolds in Trans. Am. Soc. M. E., Vol. 38, p. 799, and can be easily applied to any venturi meter used for the measurement of a gas.

DURING the winters of 1918 and 1919 the writer had occasion to measure with considerable accuracy the amount of compressed air used in connection with some research work which was being carried on at the University of Wisconsin. The venturi meter presented itself as the logical method, but aside from the mechanical difficulties of building manometers to satisfactorily stand pressures of more than 100 lb. per sq. in. the difficulties presented by the calculations where several hundred volume determinations would have to be made

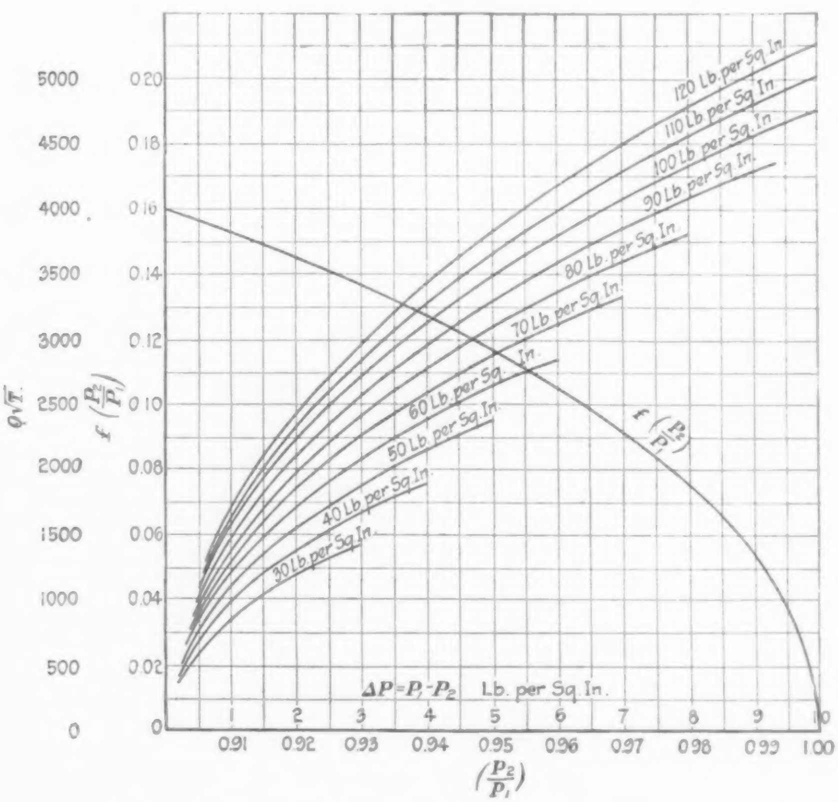


FIG. 1 FLOW CURVES FOR 1.6-IN. × 0.498-IN. VENTURI METER

were of considerable importance. Accordingly, a method of shortening the calculations was devised which reduced the entire work of one determination to a simple slide-rule computation, requiring but a few settings, and which at the same time did not affect the accuracy to any appreciable extent. Although the method of shortening these computations may seem somewhat laborious in itself, when it is remembered that with but a few changes it can be applied to any venturi meter used for the measurement of a gas, the result can be seen to have abundantly justified the means.

For presentation at the Spring Meeting, St. Louis, May 24 to 27, 1920, of THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS. All papers are subject to revision.

[1] 25 North Ferry Street.

The venturi-meter formula is given by Dr. Lucke as follows:

$$W = CA_2\left(\frac{P_2}{P_1}\right)^{\frac{1}{n}}\sqrt{2g\frac{n}{n-1}\frac{P_1}{V_1}\left[\frac{1-\left(\frac{P_2}{P_1}\right)^{\frac{n-1}{n}}}{1-\left(\frac{A_2}{A_1}\right)^2\left(\frac{P_2}{P_1}\right)^{\frac{2}{n}}}\right]}\ldots[1]$$

where W = weight of vapor or gas passing per second
C = coefficient
A_1 = area of entrance
A_2 = area of throat.

The units in which W is expressed are dependent, of course, upon the units used in all the other quantities of the formula.

Herbert B. Reynolds in Trans. Am. Soc. M. E. for 1916, p. 799, gives the following formula, which can be derived from Equation [1] by the substitution of the proper units:

$$Q = C\,\frac{3514\,A_2T_s}{P_s}\sqrt{\frac{n}{(n-1)G}}\left(\frac{P_1}{\sqrt{T_1}}\right)\left(\frac{P_2}{P_1}\right)^{\frac{1}{n}}$$
$$\times\sqrt{\frac{1-\left(\frac{P_2}{P_1}\right)^{\frac{n-1}{n}}}{1-\left(\frac{A_2}{A_1}\right)^2\left(\frac{P_2}{P_1}\right)^{\frac{2}{n}}}}\ldots\ldots\ldots\ldots\ldots[2]$$

where Q = cu. ft. per min. at 32 deg. fahr. and 14.7 lb. per sq. in.
C = coefficient (experimentally determined)
A_1 = area of entrance, sq. ft.
A_2 = area of throat, sq. ft.
T_s = absolute temperature of standard air = 492 deg. fahr.
P_s = absolute pressure of standard air = 14.7 lb. per sq. in.
n = constant = C_p/C_v (= 1.402 for air)
G = specific gravity of gas (= 1.0 for air)
P_1 = pressure of air at entrance, lb. per sq. in. absolute
P_2 = pressure of air at throat, lb. per sq. in. absolute
T_1 = temperature of air at entrance, deg. fahr. absolute.
3514 = constant determined by above choice of units

The *Sibley Journal of Engineering* (vol. 29, pp. 90-95) presents this formula in still another form, which has been derived by means of the Fourier series and is in better shape for calculation, where the ratio (P_2/P_1) is very nearly unity, or in other words, for low rates of flow. This formula is:

$$W = CA_2\left(\frac{T_s2gn}{V_sP_s(n-1)}\right)^{\frac{1}{2}}\frac{P_1}{\sqrt{T_1}}\left(x^{\frac{1}{2}}\left[\frac{n-1}{n(1-a)}\right]^{\frac{1}{2}}\right)$$
$$\times\left(1-\frac{[3+a]x}{2n[1-a]}\right)^{\frac{1}{2}}\ldots\ldots\ldots\ldots\ldots[3]$$

where V_s = volume under standard conditions = 12.38 cu. ft. per lb. for air; $a = (A_2/A_1)^2$; and $x = \Delta P/P_1$, where $\Delta P = P_1 - P_2$; the other symbols being the same as before.

Any one of these three formulæ presents a rather difficult computation as far as solution is concerned, this being especially the case in formulæ [1] and [2] because of the last radical. The log-log slide rule enables the solution to be made quite readily, excepting for values of P_2/P_1 greater than 0.98, after which it is necessary to resort to very complete logarithmic tables, or else to the third formula.

Method Used to Simplify Computations

The first step in the process of reducing these formulæ to forms which could easily be handled consisted in determining the values of A_1 and A_2 which would give a venturi meter having the desired range of capacity without making the difference between P_1 and P_2 either too great or too small for easy and accurate reading. In this series of tests it was necessary to have a range of capacity from 25 to 250 cu. ft. of free air per min. at a pressure in the venturi tube of about 100 lb. per sq. in. gage. Inasmuch as the flow is nearly proportional to the square root of the pressure

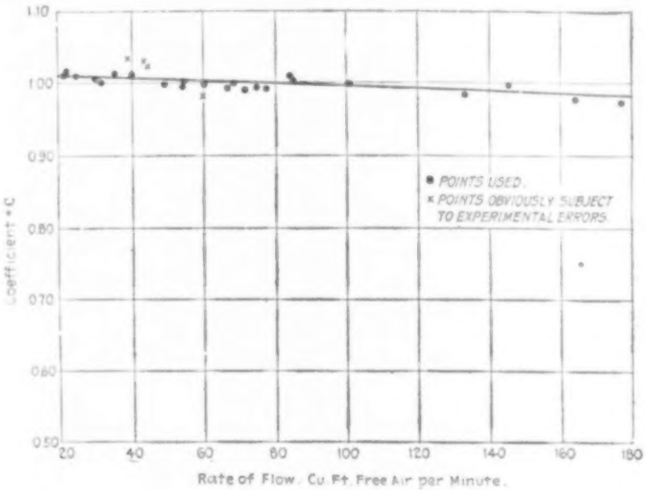


Fig. 2 Calibration Curve for 1.6-in. × 0.498-in. Venturi Meter

difference, as can be seen from formula [3], a range of possible rates of flow of 10 to 1 means a range of readable pressure differences of nearly 100 to 1 in magnitude. This necessitated the combination of a mercury and a water manometer, which will be described later.

It was found by a trial and error method that a venturi meter having an entrance diameter of 1.6 in. and a throat diameter of 0.5 in. would answer the requirements. As actually constructed, the throat diameter was found to be 0.498 in. This gave a ratio of A_2/A_1 nearly equal to 0.10.

Upon substituting these numerical values for A_1, A_2, P_s, n, and G in formula [2], there is obtained the following expression:

$$Q = 297.6C\left(\frac{P_1}{\sqrt{T_1}}\right)\left[\left(\frac{P_2}{P_1}\right)^{0.714}\sqrt{\frac{1-\left(\frac{P_2}{P_1}\right)^{0.286}}{1-0.01\left(\frac{P_2}{P_1}\right)^{1.43}}}\right]\ldots\ldots[4]$$

It can be seen that the part in brackets is independent of everything but the ratio P_2/P_1; in other words, it is a function of this ratio. Then if we let

$$f\left(\frac{P_2}{P_1}\right) = \left[\left(\frac{P_2}{P_1}\right)^{0.714}\sqrt{\frac{1-\left(\frac{P_2}{P_1}\right)^{0.286}}{1-0.01\left(\frac{P_2}{P_1}\right)^{1.43}}}\right]\ldots\ldots[5]$$

and plot a curve of $f(P_2/P_1)$ as ordinates against values of P_2/P_1, it follows that the finding of Q will merely amount to multiplying several known quantities on the slide rule, since $f(P_2/P_1)$ can be found from the curve, thus:

$$Q = C\,\frac{297.6P_1}{\sqrt{T_1}}\,f\left(\frac{P_2}{P_1}\right)\ldots\ldots\ldots\ldots\ldots\ldots[6]$$

In practice it is the quantity $P_1 - P_2 = \Delta P$ which is measured by the manometers, and the most accurate method of finding P_2/P_1 from this is as follows:

$$\frac{P_2}{P_1} = \frac{P_1 - \Delta P}{P_1} = 1 - \frac{\Delta P}{P_1}\ldots\ldots\ldots\ldots[7]$$

It can easily be seen that this last expression can be evaluated much more accurately on the slide rule than can the second.

The values of $f(P_2/P_1)$ for values of P_2/P_1 from 1.00 to 0.90 are given in Table 1 and are shown plotted out in the form of a curve in Fig. 1. The values of $f(P_2/P_1)$ for values of P_2/P_1 between 0.98 and 1.00 were found by evaluating the last two parentheses in formula [3]. It is rarely advisable to use a gas

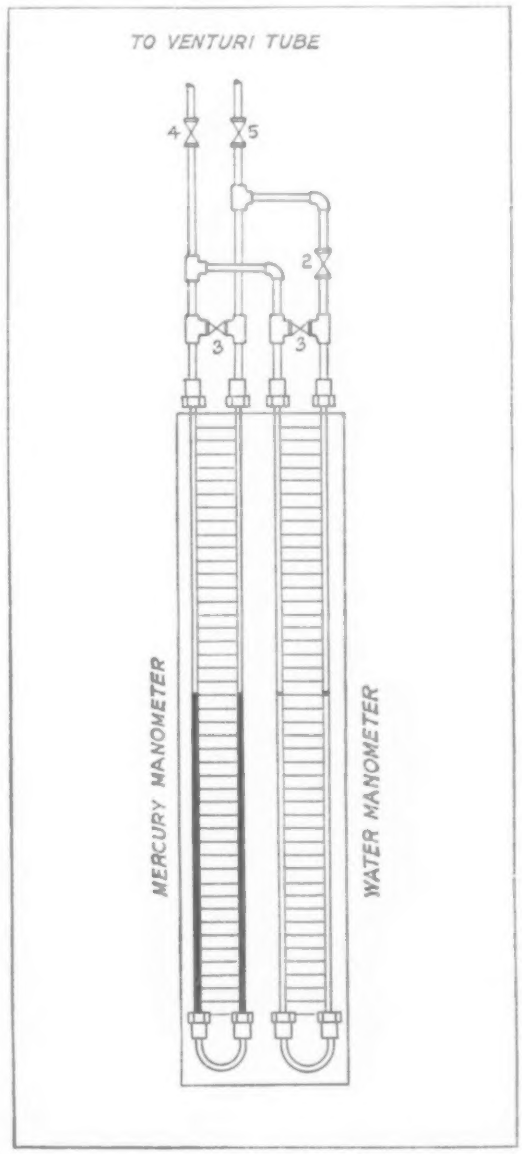


Fig. 3 Arrangement of Manometers, Piping and Valves

venturi meter at values of P_2/P_1 less than 0.90, inasmuch as the total drop in pressure across the meter becomes too great, and also because the reserve or overload capacity of the meter is so greatly restricted. This set of values is worked out for a ratio of $A_2/A_1 = 0.10$, but the effect of a slight change in this ratio upon the values of $f(P_2/P_1)$ is so slight that these values may be used for meters having a ratio differing considerably from 0.10. However, a set of values can be worked out for a tube having a ratio other than this.

The family of curves shown in Fig. 1 was worked out to facilitate rapid slide-rule calculation of the flow during a test. In order to plot these, the temperature in formula [6] was transposed to the left-hand member, thus:

$$Q\sqrt{T_1} = 297.6CP_1f\left(\frac{P_2}{P_1}\right)\ldots\ldots\ldots\ldots[8]$$

and curves for numerous values of P_1 plotted against values of

(Continued on page 260)

Tight-Fitting Threads for Bolts and Nuts

By CHESTER B. LORD,[1] ST. LOUIS, MO.

Although in general the thread forms now in use are quite satisfactory, perfection has by no means been reached. There is still considerable search for what the author of the following paper terms "a thread that will not loosen," and in the preliminary portion of his paper he discusses the fundamental principles involved in the manufacture of threads. The problem to be solved, he states, is as follows: "Without sacrifice of strength, without increase of rejection, without additional manufacturing costs, find a method whereby a male and female thread of the same lead and pitch diameter may be made after repeated loosenings to fit tight without the aid of a locking device." The reasons for departing from accepted practice are presented and discussed, and as a result of experimental work, the author draws the following conclusions: (1) The cause of stripped threads is lack of room into which the metal can flow; (2) the pitch diameter should be the same in both threads; (3) The lead should be the same; (4) The thread angle should differ by not more than 10 deg.; (5) The limits for the inside diameter of nut need not be adhered to closely, as the inner part of the nut thread holds very little, if any; (6) The outside diameter of plug and pitch diameter of both plug and nut are important and should be adhered to fairly closely.

WHAT is the cause of our periodic dissatisfaction with threads when in general they are so satisfactory? What other machine element is so easily made or is so satisfactory as regards strength? Why are there so many different kinds of threads when all are equally satisfactory, or rather unsatisfactory? Furthermore, is the dissatisfaction founded on performance or merely upon theory? Also, is the form or angle of thread a matter of importance, or merely an excuse for mathematical gymnastics? The only answer the writer has been able to elicit in reply to these various questions is that we are looking for a better thread; which statement, however, is rather indefinite and usually simply means a thread that will pass the gage. Of course, the real object of the search has been to find a thread that will not loosen.

In the past we have attributed our troubles to the fact that our fits were not close enough—the engineer's alibi for a poor design, but fundamentals cannot be violated in mechanics any more than elsewhere in nature, and we are attempting to violate two by insisting upon our present methods of inspection: (*a*) that interchangeable manufacture is a matter of percentage, which depends upon tolerance and cost; and (*b*) that a force fit is not possible between two parts the surfaces of which are complements one of the other.

Having in mind the first fundamental, it is obvious that the chances of securing a perfect fit are limited by the cost, and the second fundamental would seem to render this entirely hopeless. It is therefore proper to conclude that a good fit is usually due to error, and that if changing both male and female threads produces no relative change, changing one thread must of necessity do so. It is the object of this paper to demonstrate that by making this latter change threads can be produced that are interchangeable practically regardless of tolerance, that will not loosen, and are cheap to manufacture.

A physician always diagnoses a case before prescribing, so let us do likewise. The loosening of a thread fit is caused by vibration or repeated shock, the chief result of which is to flatten and burnish the parts of the thread that are in contact. This produces a slight looseness and the nut tends to follow the thread incline until it again fits. The same performance is repeated until finally the nut reaches an obstacle too large to flatten, or else the bolt and nut vibrate in unison and there is no further relative movement. This same phenomenon occurs in the case of a bolt screwed in a tapped hole.

The writer can remember in his shop days picking out and numbering nuts and bolts, and every mechanic knows that he cannot take the bolts out of a cylinder head on an engine of good make and put them back again indiscriminately. They must go back into the holes from whence they came. All have demonstrated to their satisfaction the fact that a tight thread will not loosen by vibration, and that one with tolerance will, unless it is prevented from loosening by a lock washer or its action is limited by some type of nut lock. We cannot lessen our tolerance because the tap wears small and the die wears large, and the lesser cannot contain the greater.

The Problem To Be Solved

To gain a better conception of the problem to be solved, consider a board cut as shown in Fig. 1. We cannot obtain a forced fit between the two pieces because one surface is the complement of the other. If we apply a force to A, we are no better off because the pieces cease to fit the instant the pressure is released. We may therefore state as a rule that where two surfaces are complementary to one another a tight fit cannot result without some means of maintaining pressure. But if we cut the board as shown in Fig. 2, theoretically removing no material, we can replace A without force, and any pressure exerted will not make a tight fit unless we distort A or drive a wedge at C. This is analogous to a perfect thread, and driving the wedge at C is equivalent to introducing a slight difference in lead. If, now, we cut off the ends of A as shown in Fig. 3, and apply a force in the direction shown, we can obtain a forced fit because only the angles are complements and because we have a method of maintaining pressure. We can also even distort A because we have room for it to expand. We have only then to provide for three things: a method of making the parts in contact absolutely complementary; the introduction of sufficient metal; and a method of maintaining pressure. With our present type of thread we can only meet one of these—namely, that of partly maintaining

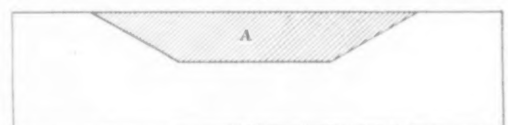


Fig. 1

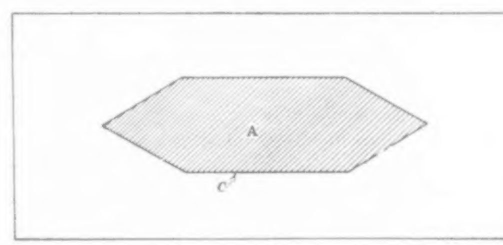


Fig. 2

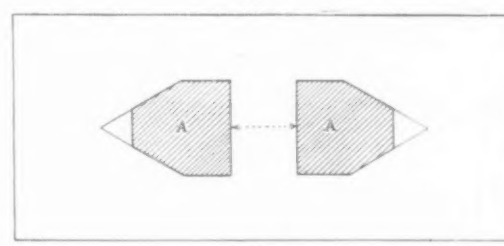


Fig. 3

Figs. 1-3 Application of Pressure in Thread Fits

[1] Consulting Mechanical Engineer, Research Engineering Co., Mem. Am.Soc.M.E.

Abstract of a paper to be presented at the Spring Meeting, St. Louis, May 24 to 27, 1920, of The American Society of Mechanical Engineers. Copies of the complete paper may be obtained gratis upon application. All papers are subject to revision.

pressure. This is demonstrated in Fig. 4, which shows in an exaggerated manner the effect of off lead.

While two slightly varying leads make a better fit, both as regards gaging and in actual use, this practice is not to be commended. Using a different lead to secure a fit is doing imperfectly on one side of the thread what the different-angle method does perfectly on both sides, because by having the leads identical and the thread supported on both sides, we secure a uniform finish instead of a distortion. Where the leads are different, the amount of distortion necessary to secure a fit increases with each thread. Thus, if the lead of a 20-thread stud is 0.05 in. and we make it 0.052 in., it will be 0.002 in. off center on the second thread and 0.018 in. on the tenth thread. This is entirely possible, and superior to a so-called perfect thread as regards fit, but a distortion, unmechanical, and unnecessary.

U. S. thread, because we have filled out the female thread tolerance as well as that of the male. We will also have uniform pressure on all flanks; the maximum possible material at the pitch line; a hard, smooth surface analogous to a case-hardened one; a fit that will remain snug despite repeated removals and that may be screwed together by ordinary means; and yet we still retain an interchangeable bolt and nut according to U. S. standards. The nut has not been changed or distorted in any way, but has simply served as a finishing roll.

The writer has stated in a previous article that, aside from threads, nowhere else in machine work do we expect micrometer limits on a roughing cut; and the question naturally arises whether an operation similar to that described would not be an effective finishing and sizing operation for commercial work. This would be the equivalent of *making* them fit the gage, and would greatly reduce the cost due to rejections. We would, of course, still have variable nuts and the necessity of sizing them.

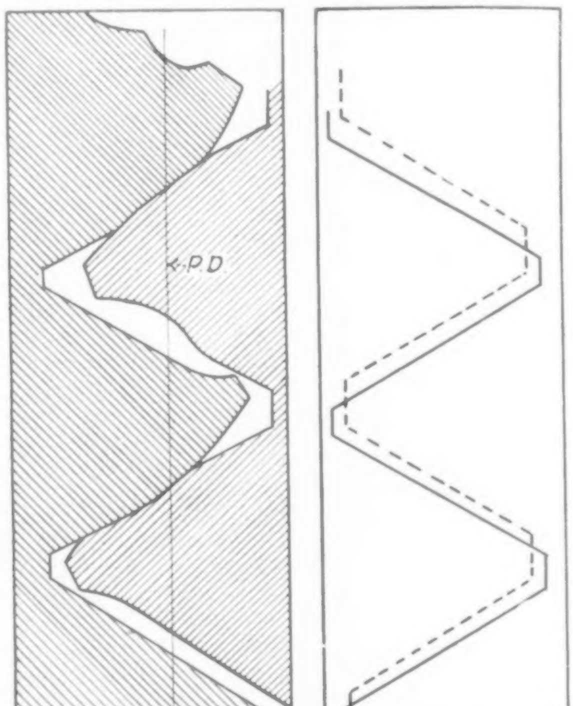


Fig. 4 The Effect of Lead (Greatly Exaggerated)

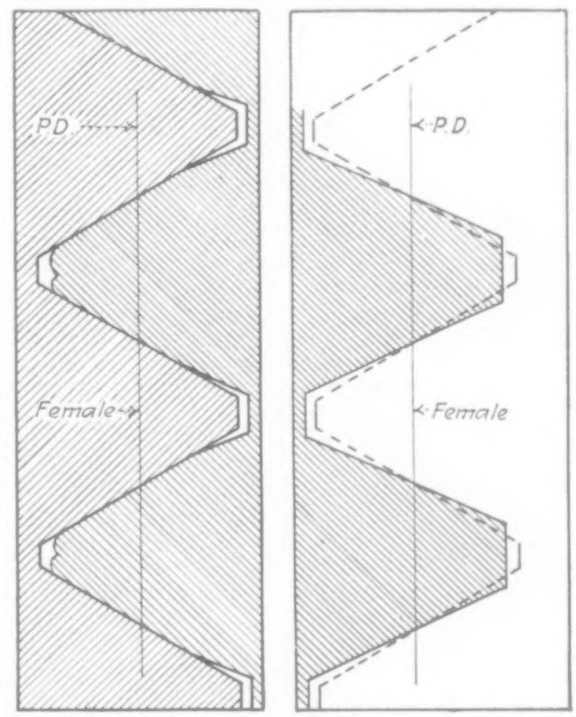


Fig. 5 Different-Angle Threads (Greatly Exaggerated)

This is what is done with railroad fish-plate bolts where the specifications state the minimum foot-pounds at which the nut and bolt may be assembled. The impossibility of meeting these requirements in quantity production is recognized by purchasing agents and most engineers, and so the lead is slightly changed. This, however, is merely a subterfuge and really defeats the purpose of the specifications in that it permits of a poorer and weaker thread than would otherwise be possible.

We are thus confronted with this problem: Without sacrifice of strength, without increase of rejection, without additional manufacturing costs, find a method whereby a male and female thread of the same lead and pitch diameter may be made after repeated loosenings to fit tight without the aid of a locking device. This, according to specifications, calls for a full thread at contact points, pressure applied continuously on all flanks, and maximum strength at the pitch line. This means the addition of surplus metal to the male (which is the only one affected) sufficient to fill out the female threads, which would be an impossibility were it not for the ductility and elasticity of steel. If we add this surplus metal we will find that we can more than fulfill the required conditions by changing the angle of the male thread to a lesser one than that of the female, having the two intersect on the pitch line.

When a male thread of this type and a standard mate are screwed together, we will have transformed a male of lesser angle to one of larger angle or of wider base than the standard

Reasons for Departing from Accepted Practice

Let us now see what authority and precedent we have for making so radical a departure from accepted practice. To do so, let us consider how threads are made, especially by rolling. Generally speaking, thread rolling is circular knurling, knurling being that process whereby the diameter of a part is increased at certain points by a corresponding reduction of diameter at other points, due to pressure alone. It is applicable to both flat and round surfaces, but for the purpose of this article we will consider only round surfaces.

In turning screws and bolts to size the diameter is held, generally speaking, to the pitch diameter. The displacement of metal from the root and lower flank forms the addendum under the process. Cutting a thread on a bolt with a die is a somewhat analogous operation, the similarity increasing as the die becomes duller. For a die-cut 1-in. bolt it will generally be found that with a diameter of 0.990 in. a fuller thread may be secured than with one of 1.000 in., the explanation being that with the die we secure a combined cutting and rolling operation. Due to lack of clearance, if the diameter is too large, part of the metal is pressed into the bottom of the die and with such force that it drags and is torn off, thus leaving a thread of smaller

outside diameter than would have been otherwise secured. This same phenomenon occurs when a nut is too tight.

If we require a holding fit on a shaft, do we use tolerances that allow of the shaft being several thousandths smaller than the hole it is to fit? Quite the contrary. We not only specify the fit but also the minimum pressure allowable to assemble the two parts, and we do this both for single units and for quantity production. We might term a shaft and rotor spider a nut and bolt with microscopic threads and assembled with a right-angled instead of a helical motion. Why not fit our bolts the same way, making our tolerances plus instead of minus and using a force fit we can depend upon when it means no change in the tools for assembly?

If we look at a finished commercial thread through a microscope, it will be seen that the edge is serrated and that slivers stand up all over its surface. By running a nut over it once we but slightly change its appearance, but by repeatedly doing so—always using a tight nut—we may finally burnish the thread so that it will not thereafter change its size and will have a surface somewhat comparable to a case-hardened one.

Fig. 5 shows diagrammatically the different-angle thread with the angles of the male greatly exaggerated to demonstrate the principle. We are complying in this case with all the conditions we have just been discussing: We are making the lesser contain the greater, angularly speaking; we are applying force from both directions, at right angles to the axis of the bolt; we have made the angles complementary—not merely two equal angles; we are securing the maximum strength at and near the pitch line, and transforming a thread with a lesser angle than that of the standard male to one with a larger angle, thus filling out the space perfectly and so doing away largely with vibration; and we are securing, whether under pressure or not, contact on all flanks, whereas the standard thread when under pressure secures contact on possibly one-half the flanks, both because it is compressible and because it does not fill the female thread. The only problem to be solved, therefore, was to find an angle of such slope that it could be formed without distortion of the nut or requiring too much force to screw home. To demonstrate this, threads as small as No. 10-32 were used, and as being of possible interest, the writer presents a brief outline of the engineers' report of the experimental work.

Results of Experimental Work

Diagrams of the different threads were first laid out on a 100 to 1 scale so as to determine approximately the most suitable angles to be tested; the Löwenherz thread with an angle of 53 deg. 8 min. being used as a basis. The nut was to have the regular Löwenherz thread with same diameter and pitch as in the 155-mm. shell adapter used by the U. S. Government.

Threads of 44 deg. and 45 deg. for the plugs seemed most favorable and accordingly the following cold-rolled-steel plugs were made up, with nuts having the same pitch diameter and lead as the plugs but a thread angle of 53 deg. 8 min.:

1 Angle of thread 44 deg. 54 min., pitch diam. 0.8748, lead 0.0787
2 Angle of thread 45 deg. 2 min., pitch diam. 0.8748, lead 0.0787
3 Angle of thread 44 deg. 0 min., pitch diam. 0.8748, lead 0.0787

Test No. 1. Nut No. 1 and plug with thread angle of 44 deg. 54 min. were screwed together *without* a lubricant. They were started about a half a thread by hand, and then an 8-in. wrench was used for about four threads. The plug was then so tight in that a 10-in. wrench was required to turn it to full depth. After a couple of backward turns the plug stuck so tight that a 20-in. wrench would not move it. The nut was then sawed open and removed from the plug and about one-third of a thread of the plug was taken off in a piece of the nut. A magnifying glass showed that the threads in both plug and nut were drawn and cut out of shape where there was a tendency for them to overlap, due apparently to too much metal and no lubricant.

Test No. 2. Nut No. 2 and plug with thread angle of 45 deg. 2 min. were screwed together *with* a lubricant. They were started by hand for about one-half turn, then an 8-in. wrench was used for five or six threads, and a 10-in. wrench for the remainder. The plug came out slightly easier than going in. After this had been repeated three times the plug could be screwed in by hand. The maximum and minimum plug gage for the nut showed no change in the thread of the nut. Under a magnifying glass it was seen that the metal had flowed to the top of the plug thread from about the pitch diameter outward. The plugs were screwed into the nuts fifty times and there was still what could be termed a "snug fit."

Test No. 7. Plugs were tried out with commercial 1-in. nuts. The thread angle of the plugs was 58 deg., and the pitch diameter 0.9228 in., with one plug this diameter plus 0.001 in., and one minus 0.001 in. This diameter allowed the plug thread in the layout to overlap the entire thread of the nut instead of only half, as in the previous cases. The nuts used were picked out of stock for size with a standard 1-in. thread gage. The smallest plug went into the nut easily by hand. The largest two went together easily with an 8-in. wrench. After being twice screwed together with the wrench they went together with a snug fit by hand. The magnifying glass showed that the thread from near the pitch diameter outward had been drawn and compressed slightly.

Test No. 9. Plugs of ½-in. diameter with pitch diameters of 0.4684 in. and 0.4699 in. (same as ½ S. A. E. nuts) and a thread angle of 50 deg. were tried with commercial ½-in. S. A. E. nuts. The difference in the two pitch diameters made practically no difference in the fits, as they both readily went in with an 8-in. wrench. After they had been screwed together four times, they would go together by hand, but without shake. After they had been screwed together 75 times there was still what could be termed a "snug fit."

Test No. 10. An attempt was made to compare the strength of an S. A. E. standard ½-in. thread with a 50-deg. thread of the same size. The plug with the standard thread on one end and the special thread on the other end was used with standard nuts. A pull of 14,000 lb. was gradually applied and the metal began to give way, which prevented an additional load. During this pull, observations were made to determine if there was any "give" in either of the threads, but both remained the same throughout. The nuts were removed and there was no apparent distortion of the threads.

Test No. 12. In this test ¼-20 plugs with pitch diameters of 0.2165 in. and 0.2181 in. with 50-deg. angle were tried out with ¼-in. U. S. standard nuts, one being a commercial nut and the other of a standard size but made in our toolroom—the tap being 0.250 in. in diameter. Both nuts were tried with a ¼-in. standard plug gage, both being apparently the same size. The nut made in the toolroom was screwed on the maximum plug and went on about one and a half times its length and then stuck and would not go either way. It was finally removed by hammering it on the sides. The threads were rolled and torn from about the pitch diameter outward, but there was not that tendency for the metal to roll upon the outside of the thread as in the previous tests, the outside diameter being only 0.251 in. as against its original 0.250 in.

The commercial nut went on the minimum plug with an extremely tight fit, but it came off very readily with the wrench and left quite a different thread from the previous one. The thread was not torn at all but rolled out to almost a perfect V-thread with outside diameters of 0.2555 in. as against the original 0.250 in. The outside diameter of the tap for the commercial nut must have been over 0.250 in. to allow this metal to flow out to 0.2555 in. and not jam the nut. If the toolroom tap had been sharper on the flats or its outside diameter greater, there would have been room for the metal in the test plug to flow out to a larger diameter and avoid tearing the thread, and consequent jamming of the nut. Two facts are clearly demonstrated: first, necessity of room for metal to flow; second, one of the limitations of the thread gage.

Test No. 13. Plugs corresponding to standard 10-32 with 50-deg. angle were tried out with standard 10-32 nuts; pitch diameters 0.170 in. and 0.1716 in. They were a little too tight a fit to go together by hand, but after being screwed together once with a wrench they went together by hand snugly.

(Continued on page 259)

Pulverized Coal in Metallurgical Furnaces at High Altitudes

By OTIS L. McINTYRE,[1] NEW YORK, N. Y.

The following paper describes experiments with pulverized coal which led to the installation of apparatus for its use in the blast furnaces, reverberatories, and sintering machines of the Cerro de Pasco Copper Corporation at La Fundicion, Peru. Information is given of the method of determining the firing performance of pulverized coal; the behavior of the various mixtures; experiences with different air pressures; and the effects of ash. The experiments were conducted at an elevation of 14,000 ft. and this fact greatly adds to the value of the data presented, for heretofore but little attention has been paid to the effects of altitude upon the burning of pulverized coal.

THE Cerro de Pasco Copper Corporation at La Fundicion, Peru, uses about 65,000 tons of coke per year, of which about 85 per cent is local coke made at the smelter, and 15 per cent is imported. This latter is very expensive, and of course both classes of coke enter largely into the smelting costs; consequently, about two years ago it was decided to determine what could be done in the way of using pulverized coal in the various departments of the smelter. The preliminary work consisted in determining the general combustibility of the local coals in pulverized form. These coals are obtained from two mines operated by the company and have the following general analysis:

Ash	Volatile Material	Fixed Carbon
26.8	40.05	33.15

This coal was dried by hand on steam hot pans to less than 1 per cent moisture, and then ground in a 4-in. by 4-in. Marcy mill, the product being stored in barrels until a sufficient quantity had been pulverized to run a test. An average screen test of this pulverized coal was about as follows:

+ 60 mesh	8.00	per cent
+100 mesh	8.00	per cent
+200 mesh	14.00	per cent
—200 mesh	70.00	per cent

The equipment used in the test is shown by Fig. 1-A and consists of coal hopper, a 3-in. feed screw driven by variable-speed motor, and a No. 2 Sturtevant blower supplying the air. The burner was a standard 6-in. pipe projecting about 12 in. into the furnace, which was approximately 4 ft. by 4 ft. by 16 ft. and constructed of firebrick. A number of tests were run with this equipment and though no pyrometric measurements were taken, observation of the furnace showed the results to be satisfactory.

The tests were first made with pure pulverized coal, and then with mixtures of coal and coke breeze, varying from 10 to 35 per cent of coke breeze, which gave practically the same results as the pure coal. The layout was then changed, Fig. 1-B, to test the practicability of using more than one burner with a single feeder. This test was run with the 4-in. return pipe both open and closed, the results indicating that satisfactory operation could be obtained by either method with a properly proportioned pipe system.

The next test made was in the sintering of fine ores on a standard Dwight-Lloyd sintering machine. These machines are oil-fired, and if coal could be substituted it would show a considerable saving. The equipment used in this test was the same as was shown in Fig. 1, except that a 1-in. screw feeder, a smaller fan, and a 2-in. pipe burner were used. This test produced a satisfactory sinter, though some trouble was encountered in the primary ignition of the coal, and the standard oil muffle proved to be too small.

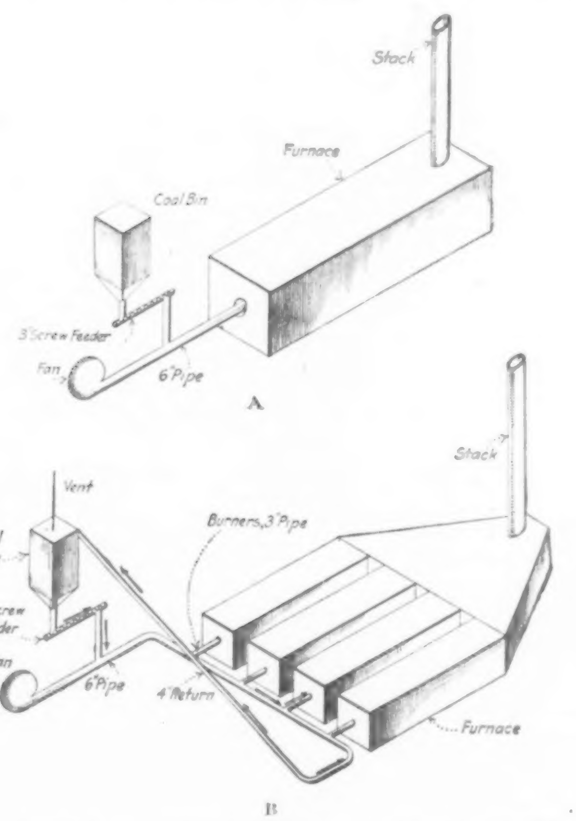


Fig. 1 Layouts of Equipment Used in Furnace Tests of Pulverized Coal

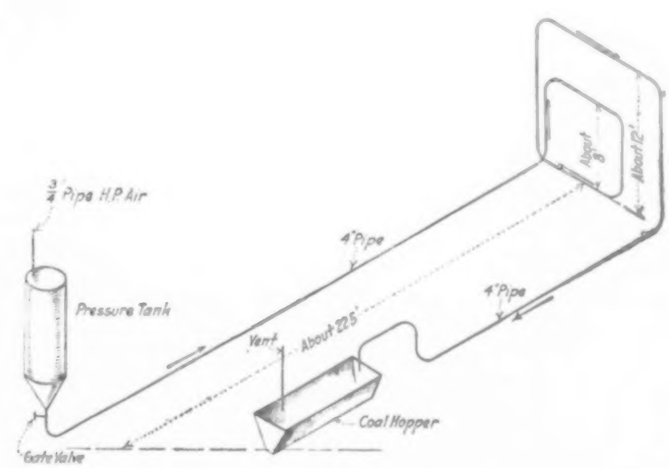


Fig. 2 Layout Used to Test Feasibility of Conveying Pulverized Coal Under Direct Air Pressure

The next experiment was to test the feasibility of conveying pulverized coal under direct air pressure. The layout used is shown in Fig. 2. Pulverized coal was placed in the pressure tank and air at 20 to 25 lb. was then admitted through the ¾-in. pipe at the top of the tank. The 4-in. valve at the bottom was then opened and the coal passed through the 4-in. piping system to the coal hopper. In this way 4000 lb. of coal was transported in 1½ to 2 min. The loss through the vent pipe varied from 100 to 200 lb. This can be taken care of by using dust collectors on the hopper, or an exhaust system which would return this waste coal to the main hopper.

For presentation at the Spring Meeting, St. Louis, May 24 to 27, 1920, of The American Society of Mechanical Engineers. All papers are subject to revision.

[1] Mech. Supt., Cerro de Pasco Copper Corpn. Mem.Am.Soc.M.E.

The foregoing tests showing up so well, it was decided to erect a larger experimental pulverizing plant. There were available for this purpose one set of 18-in. by 36-in. rolls, one 4-ft. by 4-ft. Marcy mill and two 6-ft. by 4-ft. Allis-Chalmers ball granulators. The drier consisted of five passes of 16-in. by 12-ft. screw conveyor, mounted in a brick housing on top of the reverberatory flue, and through which part of the flue gases were by-passed. The layout in plan is shown in Fig. 3.

After completing this plant it was decided to make the first experiment on the blast furnaces, so No. 5 blast furnace was selected for the purpose and was equipped on one side only, as shown by Fig. 4. The coal was ground at the experimental plant and transferred to the No. 5 furnace in a hopper car, being weighed in transit. A number of tests varying from 8 to 12 hr. were run with this equipment. The furnace air pressure averaged 34 oz., and auxiliary air for injecting coal about 22 lb. The coke charge was reduced first 25 per cent, and then 50 per cent. These tests showed up so well that it was decided to equip the other side of the furnace with coal feeders and run a test of of several days' duration. This was done and the results were entirely satisfactory. During these tests the auxiliary air was taken from the converter air line, which varied from 12 to 16 lb. pressure.

The following quantities will give an idea of the proportion of coke and pulverized coal used:

	14-Hr. Run	50-Hr. Run
Normal charge of coke, lb.	31,000	114,000
Actual charge of coke, lb.	17,000	61,800
Pulverized coal fed to furnace, lb.	8,900	41,000

The analysis and screen tests of the coal used were practically the same as noted above. The furnace performance through all tests was carefully observed and was found to be fully equal to that when operating on the normal coke charge. Two difficulties were encountered on the blast-furnace test, namely, keeping some to the feeders in operation and keeping the tuyeres open. It was observed that in some of the feeders there was a slight back pressure, due probably to partially blocked tuyeres. This did not affect materially the feeding, but forced some coal dust into the feeder bearings which mixed with the oil and finally bound the bearings so that it became necessary to shut down that particular feeder and clean the bearings. This was easily done without shutting down the other feeders, as the gears on the main shaft were mounted on feathers and provided with shifters. By using dust-proof bearings and a better-designed injector, we expect to eliminate this trouble.

Keeping the tuyeres open is absolutely essential to the safe and efficient operation of this process, and as it is a manual operation it must be handled by the operators. During these tests, tuyeres were "punched" every fifteen to twenty minutes on signal. On one occasion a tuyere became badly blocked, the feed was cut off and the tuyere cap opened. The blast from the furnace blew out a dense cloud of coal dust and molten material. The dust was ignited and burned on the outside of the furnace for 20 to 30 sec. with an intense flame about six feet long, the tuyere acting as an ordinary coal burner.

In view of the difficulty of keeping the tuyeres open and the connections airtight, it is probable that the most satisfactory place to inject the coal into the furnace would be through a separate opening in the jackets, between and preferably somewhat above the tuyeres.

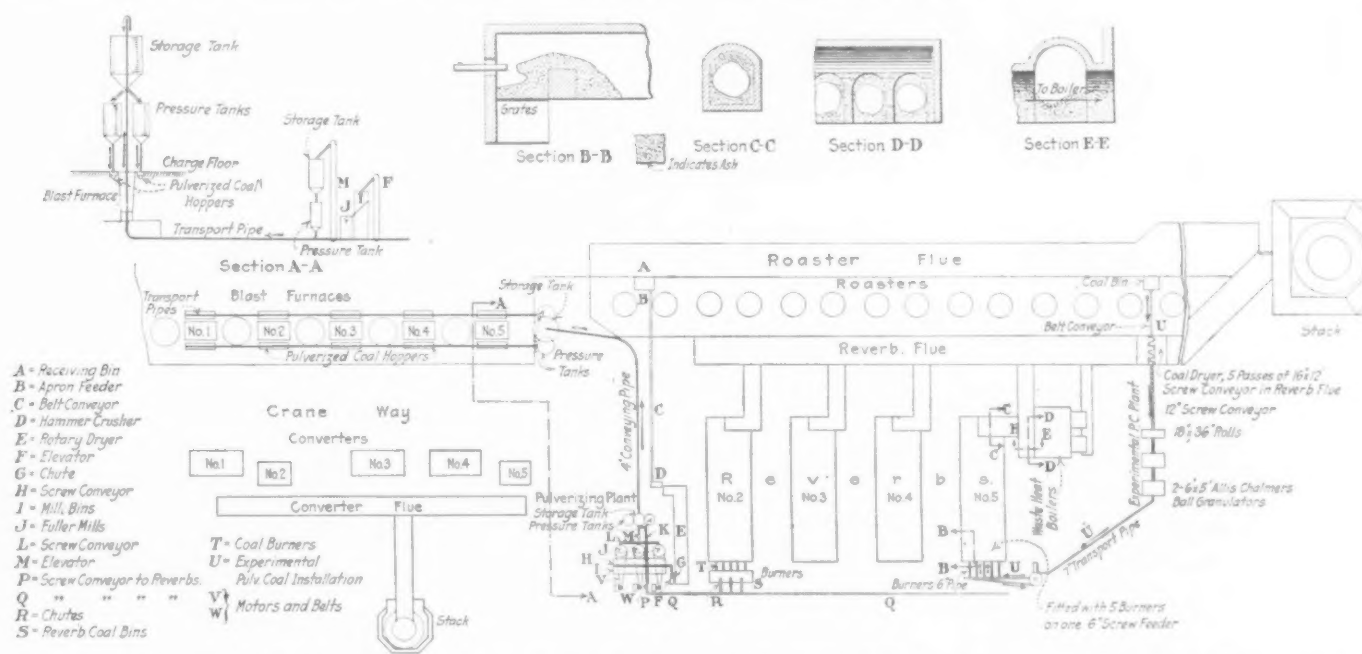


Fig. 3 Layout of Present Cerro de Pasco Copper Corporation's Smelter, Showing Location of Coal-Pulverizing Plant

The No. 5 reverberatory was selected for the final test. All four reverberatory furnaces in use are identical: they are old style, designed for hand-firing and about 18 ft. by 58 ft. inside the bridge wall. No. 5 was fitted up as shown at *U*, Fig. 3. The coal was discharged from the last mill into a hopper and dropped into a 7-in. pipe where it was picked up by an air jet and conveyed to the coal hopper, a distance of about 150 ft. and rise of about 30 ft.; the top of the hopper was constructed similar to a cyclone dust collector. From the hopper a 6-in. variable-speed screw feeder fed the coal into the suction side of a No. 9 Sturtevant Monogram blower; this in turn discharged the mixture of coal and air into the feed piping from which branched five 6-in. pipe burners into the furnace, the excess air and coal returning to the hopper.

This test was disappointing from the actual results, but when the following difficulties which were encountered are corrected, the furnace will, beyond question, show a much higher efficiency than the hand-fired furnace. First, the coal could not be dried sufficiently, the average moisture being in excess of 1.5 per cent. This introduced handling troubles. The plant would not grind sufficient coal to the required fineness, the average screen analysis being:

+ 65 mesh 22.8 per cent
— 65 mesh 8.5 per cent
— 100 mesh 25.6 per cent
— 200 mesh 42.4 per cent

The discharge from hopper to feeder was too small, and the coal continually caked and bridged. The screw feeder was too short so that the coal flushed badly at times; also the discharge from the feeder was too far from the fan so that the coal accumulated in the suction pipe and had to be removed with an air jet. Under these conditions it was obvious that uniform feeding, which is essential to efficient operation, was impossible.

This test covered about nine days, and was run for about two days with the return pipe open. Sometime during the second day the return pipe was blocked, due to overfeeding, and it was decided to continue the test without opening the run pipe, the only difference being an apparently heavier feed at the burner farthest from the fan. With a properly designed piping system, there seems to be no reason why a series of burners cannot be operated from a single feeder with or without a return. The last day's run of this test was made with a mixture of 75 per cent coal and 25 per cent coke breeze, which gave results equal to straight coal.

The following table shows a comparison between the average performance of reverberatories Nos. 2, 3, 4 and 5 over the same period:

No.	Charge Smelted Per Hr.	Coal Used per Hr.	Smelting Ratio	Hr. Run	Time Lost
Aver. of 2-3-4	5.35	2.00	2.67	262	....
5	4.63	1.99	2.33	225	37

These results are really not so bad when the troubles encountered are considered and it is remembered that this furnace was not designed for pulverized coal and that it cools very rapidly during any shutdown, and considerable time is required to bring it up to the smelting temperature again.

As ash accumulations are an important factor in reverberatory smelting with pulverized coal, close observation was made of these accumulations, and the following samples taken:

1 Ash and slag float on the bath: comes out when skimming in small and large pieces, sometimes has to be broken to pass the skimming door, is easily handled when furnace is hot, but is tough and sticky when furnace is cool.

2 Ash in boiler cross-flue: Spongy mass of ash and some slag accumulates in fairly large quantities in cross-flue between furnace and waste-heat boilers; is soft and easy to remove when first deposited, but if allowed to remain, is very difficult to remove. (See sections E-E and D-D, Fig. 3.)

3 Ash on sides of roof of furnace: Almost pure ash, lightweight and brittle when cold, appears to accumulate on sides and roof of furnace until too heavy to stick, when it drops and floats on the bath.

4 Ash in reverberatory flue, very similar to No. 2 (See Section C-C, Fig. 3).

Section B-B, Fig. 3, is taken at right angles to the bridge wall of the furnace and shows the large mass of ash, slag, unburned coal and coke which accumulated here and materially affected the operation of the furnace. This was deposited on the bridge wall and gradually built up in the shape of large horns in front of each burner, sometimes reaching within 8 or 12 in. of the burner.

Quite a large quantity of ash was deposited each shift on the boiler tubes, but was easily blown off by compressed air once or twice a shift. It was estimated that at least 50 per cent of the total ash was disposed of in the manner described, while the remainder was deposited in the main flue and went up the stack. The average ash analysis was as follows:

SiO_2	Al_2O_3	FeO	CaO	MgO	Cu
49.9	28.4	11.0	2.5	0.26	1.24

The high copper content is probably due to calcines lodging on the ash and slag float. Two samples showed Cu 2.92 and 1.91, respectively.

As a result of these experiments a modern 250-ton coal-pulverizing plant was designed and is now in course of erection. Blast furnaces, reverberatories and sinter plant will be equipped for pulverized coal, and the experiments will be continued to ascertain the equipment most suitable for local conditions, which will then be used at the new smelter now being constructed.

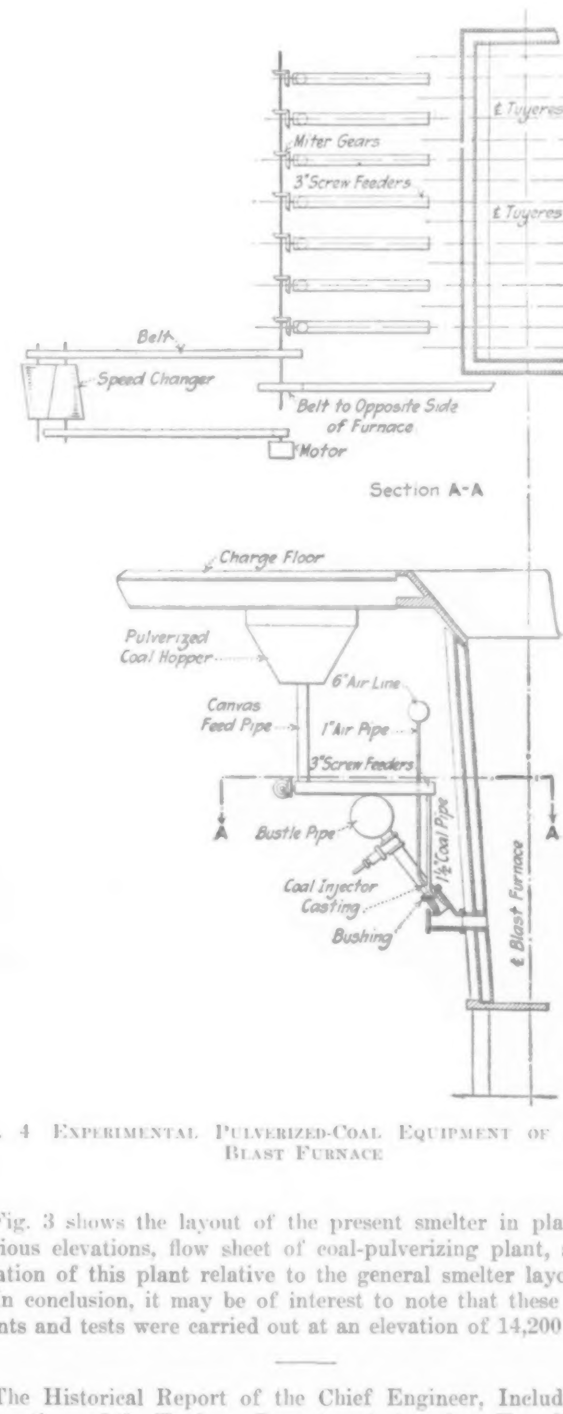


Fig. 4 Experimental Pulverized-Coal Equipment of No. 5 Blast Furnace

Fig. 3 shows the layout of the present smelter in plan, with various elevations, flow sheet of coal-pulverizing plant, and the location of this plant relative to the general smelter layout.

In conclusion, it may be of interest to note that these experiments and tests were carried out at an elevation of 14,200 ft.

The Historical Report of the Chief Engineer, Including All Operations of the Engineer Department, American Expeditionary Forces, 1917-1919, published by the War Department, consists of a main body and appendices. The main body constitutes the history of the engineers in France and is divided into three parts as follows: Part One deals with the organization and development of the department from the time of the appointment of the first chief engineer, A. E. F., May 18, 1917; Part Two is devoted to military engineering, including staff and army operations; Part Three relates to engineer activities in the services of supply, construction and forestry. The appendices consist of technical discussion, departmental and special service reports, regimental histories, and material of a similar detailed character.

The Great Hydroelectric Plant at Keokuk

Excursion to This Plant Is Planned for Members and Guests of The American Society of Mechanical Engineers in Connection with Their Spring Meeting

THE Mississippi River Power Company's power plant at Keokuk, Iowa, is by far the greatest low-head hydro-electric development ever undertaken. The entire structure is built of monolithic concrete and includes a dam, power house, navigation lock, and dry dock. Measured from end to end it is 10,560 ft., or two miles long, and is believed to be the largest monolith of its kind in the world.

It is located at the foot of the Des Moines Rapids, which extend from Montrose to Keokuk, a distance of twelve miles. In this distance the river bed has a fall of 23 ft., and the surface fall varies from 23 ft. at low water to 16 ft. at high water, which provides a normal working head for hydraulic machinery of 32 ft., varying from 21 ft. to 39 ft. according to the stage of the river. The discharge of the river, at the site of the power station, where it is approximately a mile wide, is 200,000 cu. ft. per sec. at low water and 372,500 cu. ft. per sec. at the flood stage, which discharge made possible the project.[1]

A 4650-ft. spillway dam of the gravity section type, which is surmounted by a bridge, extends from Hamilton, Ill., on the east side of the river, to the power house which is near the west side of the river. It consists of 119 arched spans, each having 30-ft. openings and 6-ft piers. Each of these 30-ft. spillways may be closed by a gate or wier; in other words there are 3570 ft. of spillway. The upstream side of the spillway section is vertical: the downstream side is rounded off into an ogee curve which discharges the flow quickly into the river below.

In order that drift and ice may be excluded from the forebay, a 2340-ft. fender pier was constructed which extends upstream from the power house and curves toward the west shore. There is a 300-ft. opening between the shore abutment and the end of the pier to allow the passage of river traffic. When navigation is closed, or when there is a large amount of floating matter in the river, this opening is closed by means of a floating boom.

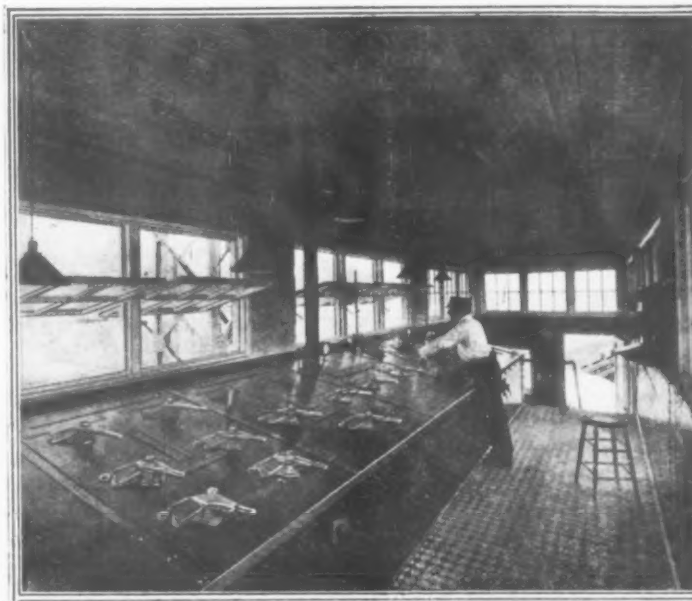
The completed power house will be 1700 ft. by 123 ft. and will provide room for 30 units each comprising a 10,000-hp. single-runner vertical Francis turbine connected to a vertical 9000-kva., 11,000-volt., 25-cycle, three-phase generator operated at 577 r.p.m. The present structure is only half of that called for by the plans, and provides for only 15 main generating units. For the substructure foundations, excavation was carried 25 ft. below the surface of the blue limestone bed of the river. From the forebay the water passes through the gate openings in the gatehouse section of the building, thence entering four branch intake tubes for each 10,000-hp. turbine. These four entry openings, 22 ft. by 7.5 ft., deliver the water to the scroll chamber at the sides and rear of the turbine setting. By the design of the scroll chamber, 39 ft. in diameter and molded in concrete to follow the mathematical curvature required, the water is impinged upon the turbine blades from all sides with equal force and velocity. The draft tubes, 18 ft. in diameter at the rotor, enlarge rapidly as they assume a horizontal direction to empty into the tail race. Because of this design the water, as it enters, moves at a speed of 14 ft. per sec. and is discharged into the tail pool at about 4 ft. per sec.

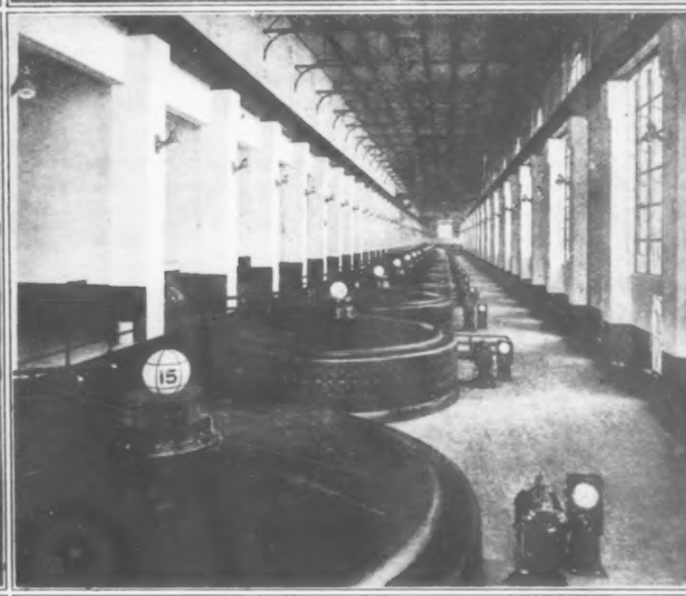
General View of the Great Hydroelectric Plant at Keokuk

A short dam, extending downstream from the power house, a navigation lock, and a dry dock at the west shore, form the forebay of the power house. The lock is a single 40-ft. lift, the chamber of which is 400 ft. by 110 ft., and may be filled in 10 minutes and emptied in 12 minutes. One of the features of this lock is the upstream gate, which may be described as a single leaf with a void chamber. This gate is operated as follows: To open it, the chamber is filled with compressed air, and because of the buoyant effect it floats into place; to close it, the compressed air is allowed to escape, and it sinks into the chamber provided for it because of its weight.

At the present time this station provides 110,000 hp. to St. Louis, East St. Louis, Alton, Hannibal, Quincy, Burlington, Ft. Madison, and adjacent territory; hence, it serves a population of about 1,120,000. With the 15 generators at the station it is possible to develop 13,500 kva.

[1] These figures are the results obtained by 20 years of observation.





Views of the Mississippi River Power Company's Plant, Keokuk, Iowa

Fig. 1 Interior of Lock Operator's House
Fig. 2 Switchboard Room, Chief Operator's Board in the Foreground
Fig. 3 High-Tension Room
Fig. 4 Main Generating Room
Fig. 5 View Showing Power House and Dam
Fig. 6 Steamboats Passing through Navigation Lock, Upper Level

Photographs obtained through the courtesy of Hugh L. Cooper & Co., Consulting Engineers, Mississippi River Power Company, 101 Park Ave., New York City

The Dissipation of Heat by Various Surfaces

By T. S. TAYLOR,[1] PITTSBURGH, PA.

Although it has long been the popular opinion that by covering hot-air pipes with sheet asbestos the heat loss was thereby reduced, some recent experiments by the author of the following paper indicate that quite the opposite is the case. Using bare tin as a standard of reference, he found that tin covered with 0.33 mm. (0.013 in.) of sheet asbestos will dissipate about 37 per cent more heat; asbestos-covered tin having a layer of dust, 32 per cent more; and tin with a layer of dust only, 7 per cent more. Calculations based on a series of tests indicate that it would require a covering of about 0.2 in. of sheet asbestos to make the loss from the covered pipe equal to that from the bright uncovered pipe. A thickness of 0.4 in. of asbestos, however, would result in a saving of 25 per cent over that of bare pipe, and about seven layers of 0.013 in. sheet asbestos loosely applied on a bare pipe would effect a saving of about 75 per cent. The author also presents figures, derived from tests, showing the effect of air velocity upon the dissipation of heat. Curves are given showing the watts dissipated per unit area and air velocity for definite surface temperature excesses of from 10 to 70 deg. The effect of the angle of incidence of the air is also discussed in the light of experimental work and it is shown that the maximum dissipation of heat takes place when air is blown over the object at an angle of from 40 to 45 deg.

NOT long ago, while conducting a series of tests to determine the relative thermal insulating properties of asbestos, it was observed that warm water placed in a plain tin vessel cooled more slowly than when placed in a similar vessel covered with thin sheet asbestos. Since this observation was in direct contradiction to popular opinion, it seemed worth while to make some definite tests on the relative dissipation of heat by such surfaces in still air. To conduct such tests tin vessels were accordingly constructed with a lid at one end and having a diameter of 10 cm. and length of 50 cm. A cylindrical heater was made by winding No. 21 constantan wire longitudinally on an asbestos-board framework so as to slip readily into the vessels. The heater was so constructed that the same amount of heat would be developed per unit area of surface of the vessels, both sides and ends. This made it possible to maintain the temperature within the vessel at various values above the surrounding air temperature.

The outer surfaces of the vessels were as follows: plain bright tin; tin covered tightly with 0.33-mm. (0.013 in.) sheet asbestos; tin covered loosely with three layers of 0.33-mm. asbestos; tin aluminum-painted; galvanized; and various dust-covered surfaces. A thermometer inserted through the side of each vessel provided means for measuring the temperature at the center of the vessel, and thermocouples of 0.005-in. copper-constantan wire were attached to the outer surface of each vessel so as to measure their surface temperatures. The vessels were always placed horizontally in such positions in the room as to be free from unnecessary convection currents.

Observations were taken of the amounts of electrical energy, measured by ammeter and voltmeter, necessary to maintain various differences between the temperature within the vessel as determined by the thermometer and the surrounding temperature. Surface and room temperatures were also taken at the same time. The room temperature was taken at points sufficiently distant from the vessel to be uninfluenced by it. In this manner results were obtained showing the watts dissipated per unit area for various temperature excesses, internal above room, for different surfaces. Curves 1 and 2 in Fig. 1 show the results obtained for tin covered tightly with 0.33-mm. sheet asbestos and bare tin, respectively. Curves 1′ and 2′ give the relations in watts per sq. cm. per deg. cent. plotted against temperature for the corresponding surfaces. It is seen that the dissipation of heat per unit area per degree of temperature excess increases almost uniformly with the temperature difference over the range of temperatures used. Thus the curves 1 and 2 can be represented approximately by the relation, $W = AT + BT^2$; where W is the watts dissipated per unit area, T the temperature excess (internal above surrounding air) and A and B constants for each surface.

Table 1 gives the values of the heat dissipated by the various

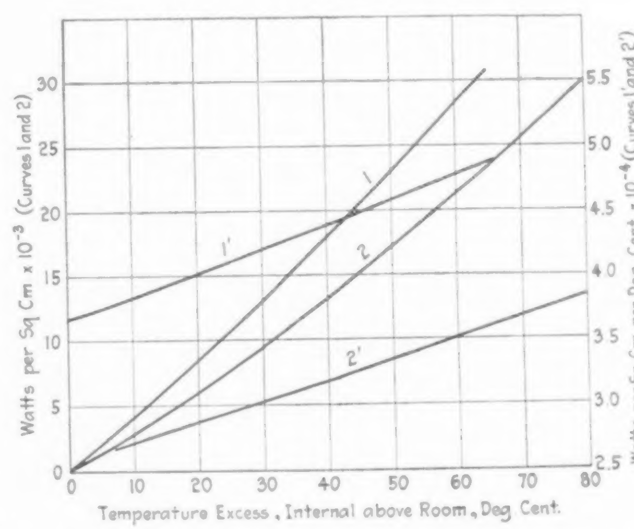


Fig. 1 Heat Dissipated From Tin Tightly Covered With 0.33-mm. Sheet Asbestos

surfaces at corresponding temperature excesses. In addition to the surfaces listed in Table 1, results were also obtained for galvanized surface and tin *loosely* covered with three layers of sheet asbestos when dust-covered. Table 2 gives the relative

TABLE 1 HEAT LOSSES FROM VARIOUS SURFACES

All values are expressed in watts per sq. cm. $\times 10^{-3}$.

Temperature excess internal above room deg. cent.	No 3—Bare Tin	No. 1—Tin covered tightly with 0.3-mm. asbestos	No. 1 — Covered with dust	No. 3 — Covered with dust	No 5—Galvanized sheet iron	No. 6—Tin covered with 3 layers asbestos paper	No. 7—Tin, aluminum-painted
5	1.33	1.87	1.75	1.40	1.50	1.50	1.60
10	2.70	3.80	3.62	2.90	3.00	3.00	3.20
15	4.09	5.90	5.60	4.55	4.70	4.65	4.85
20	5.70	8.00	7.70	6.20	6.36	6.20	6.66
25	7.18	10.30	9.85	7.95	8.20	7.85	8.60
30	9.09	12.70	12.06	9.85	10.11	9.60	10.45
35	10.99	15.15	14.35	11.75	12.15	11.35	12.35
40	12.88	17.51	16.90	13.85	14.20	13.15	14.35
45	14.90	20.15	19.50	15.90	16.35	14.90	16.50
50	16.90	22.20	22.10	18.10	18.50	16.85	18.70
55	19.03	25.45	24.70	20.35	20.85	18.80	20.90
60	21.24	28.35	27.60	22.50	23.00	20.75	23.15
65	23.40	31.40	30.25	24.87	25.30	22.70	25.45
70	25.55			27.15	27.65	24.70	27.75
75	27.90			29.35		26.70	30.20

[1] Mellon Institute, University of Pittsburgh; formerly of the Westinghouse Electric & Manufacturing Company.

[2] Since compiling these results the writer has learned that somewhat similar results have been observed independently by V. S. Day at the University of Illinois and were noted at the meeting of the National Warm-Air Heating and Ventilating Association, Columbus, Ohio, June 11, 1919. Observations showing the results outlined in the earlier portions of the present paper were first taken about February 1, 1919. Nothing further was done at that time owing to the pressure of other work. Recently, however, occasion permitted further work and the results confirmed the original ones. A preliminary notice of the present results appeared in Mechanical Engineering for January, 1920, p. 69.

Abstract of a paper to be presented at the Spring Meeting, St. Louis, May 24 to 27, 1920, of The American Society of Mechanical Engineers. Copies of the complete paper may be obtained gratis upon application. All papers are subject to revision.

amounts of heat dissipated as compared with bare tin for corresponding differences in temperature. Tin covered tightly with one layer of 0.33-mm. sheet asbestos will dissipate 37 per cent more heat in still air than the bare tin. Even when both are covered with dust, such as that usually found on furnace pipes, the asbestos-covered surface will lose 23 per cent more heat than the bare one. The effect of dust on the pipes is to increase the loss of the bare pipe and decrease the loss of the asbestos-covered one. It requires at least three layers of 0.33-mm. sheet asbestos applied loosely on a bare pipe in order to dissipate no more heat than the uncovered bare pipe. This is readily shown by Table 2.

It will be observed from a study of Table 2 that the ratio for

TABLE 2 HEAT DISSIPATED BY VARIOUS SURFACES AS COMPARED WITH THAT DISSIPATED BY BARE TIN No. 3.

Temperature excess internal above room deg. cent.	No. 1—Tin covered with 0.33-mm. sheet asbestos.	No. 1—Dust covered	No. 3—Dust covered	No. 5—Galvanised sheet iron	No. 6—Tin covered loosely with three layers asbestos	No 5—Dust covered	No. 6—Dust covered	No. 7—Tin, aluminum-painted
5	1.41	1.32	1.05	1.13	1.13	1.18	1.01	1.20
10	1.41	1.34	1.07	1.11	1.11	1.19	1.02	1.18
15	1.43	1.37	1.11	1.14	1.13	1.18	1.05	1.18
20	1.40	1.34	1.09	1.11	1.09	1.17	1.03	1.17
25	1.40	1.33	1.08	1.11	1.06	1.18	1.02	1.17
30	1.40	1.33	1.08	1.11	1.05	1.18	1.02	1.15
35	1.38	1.30	1.07	1.10	1.03	1.17	1.02	1.12
40	1.37	1.31	1.04	1.10	1.02	1.19	1.01	1.12
45	1.35	1.32	1.07	1.10	1.01	1.20	1.01	1.11
50	1.34	1.31	1.08	1.10	1.00	1.20	1.00	1.11
55	1.33	1.30	1.07	1.10	0.99	1.20	1.00	1.10
60	1.34	1.30	1.06	1.08	0.98	1.20	0.99	1.09
65	1.34	1.28	1.06	1.08	0.97	1.19	0.99	1.09
70			1.06	1.08	0.97		0.98	1.09
75			1.05		0.96		0.97	1.08
Me	1.37	1.32	1.07	1.10	1.05	1.19	1.01	1.13

all surfaces with respect to the bare pipe becomes somewhat smaller with increasing temperature excess. This indicates that if the temperature difference were high enough, very little difference would exist between the amounts of heat dissipated by each. This condition would not exist, however, until the surface temperatures were such that the heat would be lost chiefly through radiation, which for the present temperature range plays but little part.

Heat Losses from Hot-Air Pipes

One very interesting feature about these results is their application to the loss of heat by hot-air furnace pipes. From the results in Tables 1 and 2 it is quite evident that hot-air-furnace pipes lose more heat when coated with the usual sheet asbestos than when left bare. Furthermore, this difference is too great to be merely given a casual consideration, and the following brief discussion will emphasize the point. Let us consider in the first place what thickness of covering would be necessary in order to insure no more loss of heat by the covered pipe than by the uncovered one. For the same temperature excess, say, 40 deg. cent. internal above surrounding air, the covered pipe loses 17.52×10^{-3} watts per sq. cm. while the bare pipe loses 12.70×10^{-3}. This is seen by reference to curves 1 and 2 in Fig. 1. Experiments show that a covered pipe (No. 1) to lose only 12.70×10^{-3} watts per sq. cm. would require an outer-surface temperature excess of 12.8 deg. cent., and that when losing 17.52×10^{-3} watts per sq. cm. its surface temperature excess is 17.2 deg. cent. Hence sufficient insulation must be added to reduce the surface temperature to the lower value, or there must be enough asbestos added to produce a drop of 4.4 deg. (17.2 — 12.8). The thickness of asbestos necessary is given by the following equation:

$$12.7\times10^{-3}\times 0.239=\frac{4.4\times 0.00035}{d}$$

where 0.239 is the factor to reduce watts to calories and 0.00035 the thermal conductivity of asbestos paper in calories per cm. per sec. Solving the equation for d gives a value of 0.51 cm., which is practically 0.2 in. While this is an approximate solution it shows that considerably more thickness of insulation should be applied to hot-air pipes in order to make them as efficient as if they were left bare.

It is interesting to speculate as to the possible saving that would result by leaving the pipes bright and uncovered. Suppose there is a temperature excess, internal above surrounding air, of, say, 40 deg. cent. (72 deg. fahr.). As is shown above this corresponds to a loss of 17.52×10^{-3} watts per sq. cm. or 0.113 watt per sq. in. from the covered pipe. If we have 10 pipes 10 ft. long and 10 in. in diameter, that is, approximately 36,000 sq. in. of surface, the total loss would be $0.113 \times 36,000 = 4068$ watts. The total loss per day would be $4068 \times 24 \times 3600$, or 3.52×10^8 joules. One pound of coal has a heating value of approximately 12,500 B.t.u. $= 1.32\times10^7$ joules. Consequently the loss in pounds of coal per day would be $3.52\times10^8 \div 1.32\times10^7$, or 26.6. This would be equivalent to about 75 bu. during the heating season. The loss through a bare pipe would be equivalent to $100 \div 137$ (see Table 2) of this value, or about 54 bu. These considerations indicate, therefore, that the pipe system in question covered with 0.33-mm. sheet asbestos will lose during a winter season a quantity of heat equivalent to that obtained from 20 bu. of coal more than the same system would lose if left uncovered.

The explanation of the larger loss through a pipe when covered

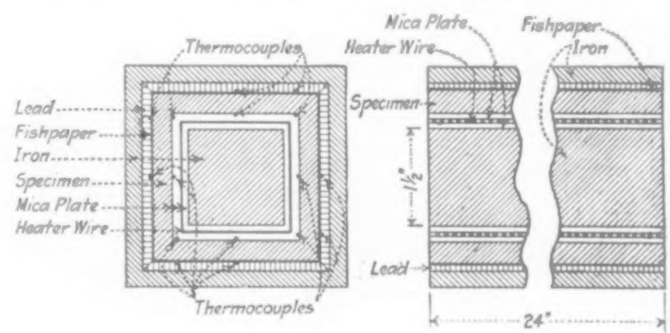


Fig. 2 Apparatus Used in Measuring Heat Losses

with a thin layer of asbestos is due to the fact that the asbestos surface is some three or four times as great as the plain tin surface so far as molecular dimensions are concerned. The loss being due chiefly to air contact, it is readily seen that the greater the surface for the molecules to come into contact with, the more heat will thus be liberated. The radiating power of the asbestos also being larger than that of tin, will contribute an additional amount to the advantage of the asbestos as far as heat loss is concerned. The loss due to radiation, however, at these temperature differences is quite small compared with that lost by convection currents. Since the asbestos surface facilitates the loss of heat due to its increasing the effective molecular contacts, the surface of the asbestos and also the outer surface of the tin will thus have their temperatures considerably decreased and the result will be that more heat must pass through the tin and asbestos as a consequence of this condition. Therefore, when the surface of the pipe is thus changed and the heat losses increased for a given temperature gradient, it is necessary to overcome this by increasing the thickness of the asbestos layer to such an extent that the thermal resistance of the pipe and asbestos or insulation will cut down the heat flow to the desired amount. That is, the radiation resulting from increasing the effective area must be counteracted by increasing the thermal resistance through the addition of a greater thickness of insulation.

Influence of Air Velocity on Dissipation of Heat

The work described under this heading was primarily undertaken for the purpose of securing data useful to engineers in

designing electrical apparatus. The results obtained are for the surface of a typical end coil of a turbo-generator, but they nevertheless are of value to anyone who is interested in the problem of air cooling. The apparatus upon which the wrapper, composed of treated cloth and tape, was placed was the same as had been previously used in measuring the thermal conductivities of coil wrappers (see *Electrical World*, February 14, 1920, p. 369). An iron bar $1\frac{1}{2}$ in. by $1\frac{1}{2}$ in. by 24 in. was used as a core in order to secure rigidity. A layer of $\frac{1}{16}$-in. heater mica was pressed over the core and a heater wire of No. 21 constantan wound over the mica so as to have eight turns to the inch. The

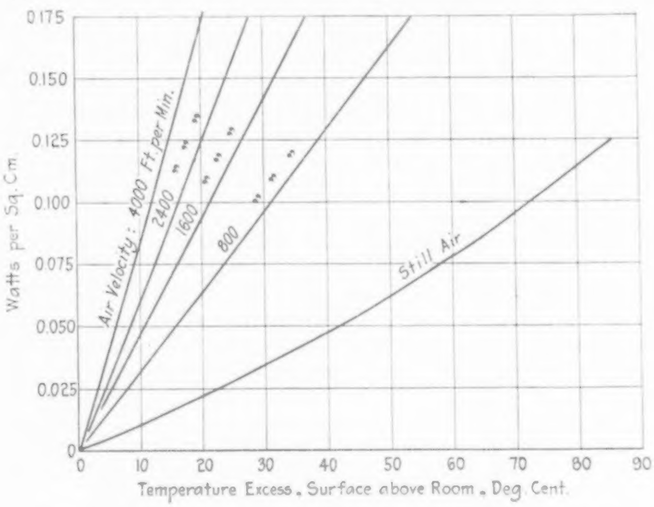


FIG. 3 EFFECT OF AIR VELOCITY ON DISSIPATION OF HEAT

space between the turns was filled with asbestos cement and a second layer of $\frac{1}{16}$-in. heater mica plate was then pressed over the entire apparatus. After having been thoroughly dried out by sending a current through the heater wire while the entire heater was held between clamps, the apparatus was wrapped with the insulation according to definite specifications. Two thermocouples were placed on the wrapper on each side of the heater, one at the center of each side and another at the edge at corresponding positions along heater. The thermocouple wires (0.005 in. copper and constantan) were run out along the heater its entire length, the copper ones to one end and the constantan to the other. A sketch of the heater is shown in Fig. 2.

The heater after having been thus wrapped and arranged was placed about eight inches in front of the outlet of a blower and parallel to the opening so that the air stream fell at right angles upon it. The ends of the heater were covered with wool felt to prevent loss of heat therefrom. The outlet from the blower was of such dimensions ($2\frac{1}{4}$ in. by $2\frac{1}{4}$ in. by 24 in.) that the coil was completely within the air stream. Baffle plates placed in the air channel made it possible to secure a symmetrical distribution of the air stream. A small pitot tube made from a hypodermic needle was used to measure the velocity. The differences of pressure were read on a differential draft gage. Observations were also made of the air temperature and barometric pressure. The velocity of the air (V) was calculated for standard conditions, 760 mm. pressure and 25 deg. cent. temperature, by use of the formula

$$V = \sqrt{\frac{2\,ghd}{d'}}$$

where g is the acceleration due to gravity, h the height of the liquid in the differential gage, d the density of this liquid, and d' the density of the air.

Measurements of the air velocity at the point in the air stream where the coil was situated showed but little variation from that for corresponding points at the opening. At least, whatever variation did exist was of the same order of magnitude as the experimental error. It was therefore assumed that the average of the velocity would be a fair value to take as the velocity of the air blowing over the coil.

The current in the heater was maintained constant and a constant number of watts were thus dissipated per unit area. Observations were taken of the excess of the surface temperature of the coil (determined from the average of the eight thermocouples on its surface) above the temperature of the impinging air for various air velocities and it was found that the heat liberated per degree excess increases approximately uniformly with the velocity over the range of velocities investigated.

In the above manner relations were determined for various amounts of heat liberated up to 0.186 watt per sq. cm (1.2 watts per sq. in.). From these values relations were obtained between the watts dissipated per sq. cm. and the corresponding temperature excess of the surface above air temperature for various air velocities. The curves in Fig. 3 show the watts dissipated per sq. cm. and corresponding temperature excesses for air velocities of 0, 800, 1600, 2400, and 4000 ft. per min. For still air it is seen that the amount of heat liberated per degree of temperature excess increases with increasing temperature excess. On the contrary, it is seen that the watts liberated per unit area per degree excess is practically constant for all air velocities other than natural convection currents. The watts dissipated per unit area varies uniformly with the temperature excess for constant air velocities. However, it is not safe to assume from these

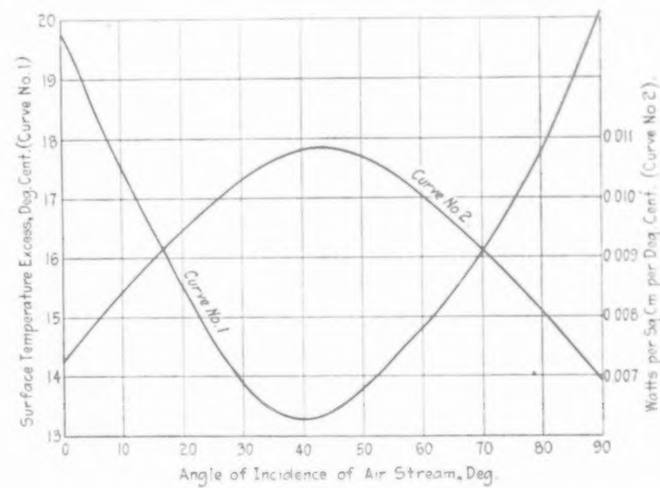


FIG. 4 EFFECT OF ANGLE OF INCIDENCE ON DISSIPATION OF HEAT

experiments that such linear relationships continue to hold indefinitely as the watts dissipated increases.

EFFECT OF ANGLE OF INCIDENCE OF AIR STREAM

All the foregoing results were obtained for perpendicular incidence or when the angle of incidence of the air stream was zero. From results that had been obtained previously on the cooling of a very small coil of wire ($\frac{1}{8}$ in. in diameter) when placed in an air current, it was seen that the amount of heat dissipated for a given temperature excess was different for different angles of incidence of the air stream. It therefore seemed worth while to make some tests to determine the way in which the temperature excess of the surface of the coil wrapper varied with the angle of incidence for a definite amount of heat dissipated per unit area and constant air velocity. This was done for a dissipation of 0.145 watt per sq. cm. (0.938 watt per sq. in.) and an air velocity of 3267 ft. per min. Curve No. 1, Fig. 4, shows how the temperature excess changes under the above conditions as the angle of incidence of the air stream changes from 0, that is, perpendicularly, to 90 deg. or parallel to the coil. Curve No. 2 shows how the watts per sq. cm. deg. cent. changes with the angle of incidence. The curves are quite interesting in that they show the relative cooling effects of air at various angles of incidence. It is seen that the temperature excess for the particular air velocity of 3267 ft. per min. and a dissipation of 0.145 watt per sq. cm. at an angle of incidence of air stream of about 40 to 45 deg. is only 67 per cent of what it is for an angle of incidence

(*Continued on page* 259)

ENGINEERING SURVEY

A Review of Progress and Attainment in Mechanical Engineering and Related Fields, as Gathered from Current Technical Periodicals and Other Sources

SUBJECTS OF THIS MONTH'S ABSTRACTS

AERONAUTICS

Muffler Design; Back Pressure in Exhaust Line and Power Loss of Aeroplane Engines

Investigation of Muffling Problem for Aeroplane Engines, G. B. Upton and V. R. Gage, Members Am.Soc.M.E. Data of tests carried out under the auspices of the National Advisory Committee for Aeronautics on a Curtiss aeroplane engine and several stationary and other engines, using a fan dynamometer.

The paper describes in considerable detail the methods of measurements and the formula used. As regards the relation between back pressure and power output, it appears to have been found that for moderate back pressures the power loss is substantially proportional to the back pressure, while for higher back pressures the power loss mounts rapidly, apparently at such a rate that a back pressure of even less than 10 lb. per sq. in. would stop the engine.

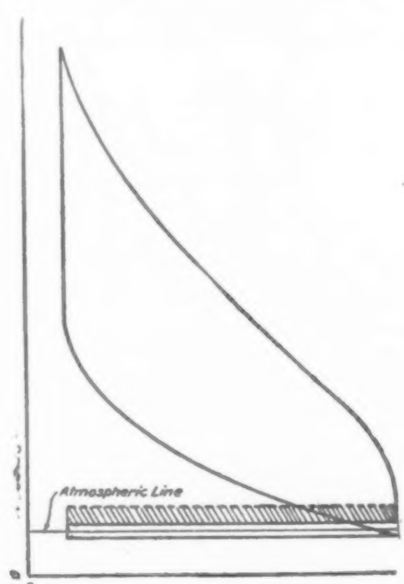


Fig. 1 Indicator Diagram Showing Loss of Power Through Back Pressure at Exhaust Valve

A possible explanation of this changing effect of back pressure as the back pressure increases may be found by considering the indicator card. This is schematically shown in Fig. 1. For small back pressures we may expect the main effect to be a lifting of the exhaust line of the card by an amount substantially equal to the increase of back pressure. The result would be a loss of indicated mean effective pressure equal to the back pressure, because the elevation of the exhaust line would extend through the whole stroke. The loss of brake mean effective pressure will be smaller than the loss of indicated mean effective pressure in the ratio of the mechanical efficiency of the engine to unity.

At higher back pressures the exhaust gases are held back in greater amounts in the cylinder, leaving the clearance space, at the end of the exhaust period, filled with an abnormal weight of hot, dead gases. These reëxpanding, interfere with the incoming charge in various ways, lessening the amount of the fuel mixture drawn in. The decrease of charge quantity will result in a decrease of the mean effective pressure which is added to the decrease of mean effective pressure due to lifting of the pressure of the exhaust line.

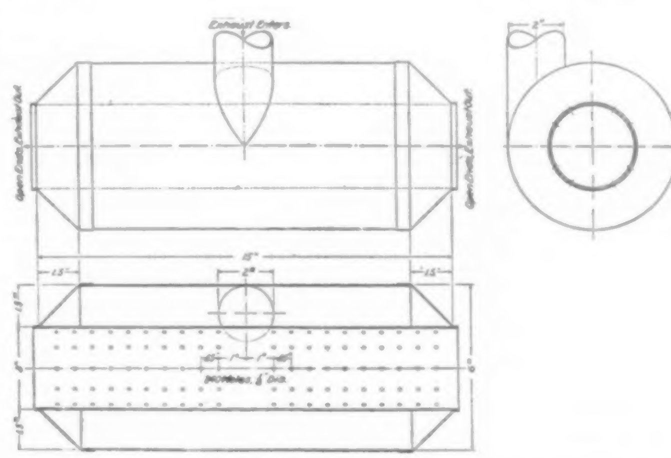


Fig. 2 Tangential-Whirl-Chamber Tank Muffler Recommended by the National Advisory Committee for Aeronautics for the Liberty Aeroplane Engine

Probably it is the decrease of charge which is the principal reason for the possibility of stalling the engine by fairly completely choking the exhaust pipe and before complete closure is reached.

It was also found, as regards the relation between the brake horsepower and the actual back pressure, that "the back pressure increases as some exponential function of the horsepower, when the conditions of the exhaust passages remain unchanged" [quoted literally.—Editor.].

Data are presented to demonstrate that the choking of the exhaust by sharp turns, pipe fittings, etc., gives the same results as choking by a muffler.

In the course of the experimental work carried out some peculiar phenomena were noted. One such was the abnormal power drop,

considering the back pressure, at certain critical speeds. It was found that this abnormal power loss could be avoided by a very small change of speed either way from the critical.

The critical speed changed or disappeared with change of exhaust manifold. The supposed cause of this abnormal power loss at the critical speed is a reflected wave of exhaust gas killing the clearance of some cylinder just before its exhaust valve closed.

A number of mufflers were tested.

The authors recommended a tentative design for the Liberty 12-cylinder engine, that shown in Fig. 2, where air is supposed to pass through the inner tube to some extent aiding in cooling. (*National Advisory Committee for Aeronautics*, Report No. 55, preprint from Fifth Annual Report 1919, 38 pp., 27 figs. and numerous tables, *e*)

Blast Engine with Reaction Jet Propulsion

MÉLOT SYSTEM OF AIRCRAFT PROPULSION. At the recent Paris aeronautical show there was exhibited a trial machine embodying the Mélot principle of propulsion. It is stated that the inventor experimented during the war at the Laboratoire du Conservatoire des Arts et Métiers in coöperation with the French Ministry in Munitions.

The machine consists of a burner with fireproof lining. Into this an explosive mixture is injected and ignited in the first instance by a spark plug, after which combustion continues uninterruptedly. The burned gases are exhausted through a blast

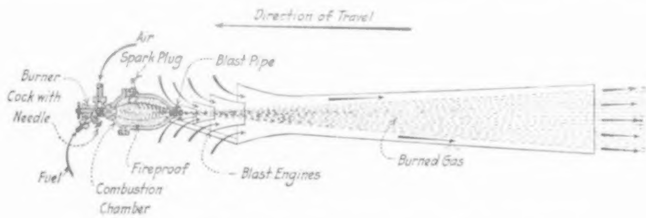


FIG. 3 MÉLOT SYSTEM OF PROPULSION FOR AIRCRAFT

pipe and four blast "engines," which are really graduated nozzles, one large and three small.

At the inlet mouth of each of these nozzles air is drawn in by suction, and the whole mixture of air and burned gases is exhausted by the last and largest blast engine and makes a direct thrust against the air at the rear of the engine (Fig. 3).

The machine is said to give 30 hp. for a relative speed of 50 m. (164 ft.) per sec. The weight per horsepower is said to be 0.5 kg. (1.1 lb.), and it is obvious that if the machine is capable of functioning for any length of time, its cost ought to be quite low because of the absence of valves, pistons and other parts of the conventional engine. (*Aeronautics*, vol. 18, no. 331 (New Series), Feb. 19, 1920, p. 157, 2 figs., *d*)

THE AERODYNAMIC PROPERTIES OF THICK AEROFOILS, F. H. Norton. A report dealing with the results of a series of tests conducted at the Massachusetts Institute of Technology wind tunnel, with a view to developing aerofoil sections thick enough to permit of internal bracing and the use of cantilever wings without any external bracing of the airplane wing truss. The sections tested were based on the Durand 13, and were varied in section form, in thickness along the span, and in chord along the span. Tapering both in thickness and in chord was found to be highly beneficial to efficiency, and some of the wings developed have L/D ratios practically as high at angles corresponding to very high speeds of flight as the best of the wing sections for normal type, together with very much higher maximum lift coefficients. In particular, it was found that the substitution of a thick tapered wing for R. A. F. 6 on a 3600-lb. fighting biplane with Liberty engine would increase the maximum speed by 18 m.p.h., due to the saving in parasite resistance by entire elimination of the interplane bracing. Report No. 75 of the *National Advisory Committee for Aeronautics*, preprint from Fifth Annual Report 1920, pp. 5-26, 29 figs., *te*)

BUREAU OF STANDARDS

VAPOR PRESSURE OF AMMONIA, C. S. Cragoe, C. H. Myers and C. S. Taylor. The previous measurements of the vapor pressure of ammonia are briefly reviewed and tabulated. A detailed description is given of the apparatus and method employed in the present measurements throughout the temperature interval — 78 deg. to + 70 deg. cent. Seven samples of thoroughly purified ammonia were used. Special tests showed less than one part in 100,000 by volume of non-condensing gases and less than 0.01 per cent by weight of other impurities. The methods of purification and filling manometers are briefly described. The phenomenon of hysteresis was observed near the normal boiling point of ammonia with a commercial sample containing a small amount of air, which indicated the necessity of very complete removal of dissolved gases for any accurate measurements of vapor pressure by the static method. Lags in coming to equilibrium were encountered and studied in order to determine the most advantageous procedure in establishing equilibrium. The normal boiling point of ammonia was determined by the static and also the dynamic method, the mean of the results by the two methods being —33.35 deg. cent. Two empirical equations were found to represent closely the results in the temperature range covered experimentally and also the latest determination of the critical data for ammonia. The results of 122 measurements in the interval — 78 deg. to + 25 deg. cent. made with direct observations of mercury columns agree with the empirical equations within 1 mm. of mercury. The results of 28 measurements in the interval + 15 deg. to + 70 deg. cent. made with an accurately calibrated piston gage agree with the empirical equations within about 3 mm. of mercury. As a final result the vapor pressure of ammonia is expressed in the range — 80 deg. to + 70 deg. cent. by either of the following equations:

$$\log p = 30.256818 - (1914.9569/\theta) - 8.4598324 \log \theta + 2.39309 \times 10^{-3}\theta + 2.955214 \times 10^{-6}\theta^2$$

$$\log p = 12.465400 - (1648.6068/\theta) - 0.01638646\theta + 2.403267 \times 10^{-5}\theta^2 - 1.168708 \times 10^{-8}\theta^3$$

where p is expressed in mm. of mercury and θ in degrees absolute (deg. abs. = deg. cent. + 273.1). (*Abstract of Scientific Papers of the Bureau of Standards* No. 369, *e*)

ENGINEERING MATERIALS

Does Pickling Affect the Quality and Machinability of Steel?

EFFECT OF PICKLING ON ALLOY STEEL, H. L. Hess, Mem.Am. Soc.M.E. Pickling is extensively used, as it facilitates the discovery of seams and surface defects generally, and removes all furnace and rolling scale. Various solutions are used, such as highly diluted baths of sulphuric or hydrochloric acids.

A series of tests were carried out by the metallurgical department of the Hess Steel Corporation, Baltimore, Md. In these tests 1 lb. of a special pickling compound (not otherwise specified) was dissolved in 3 gal. of water, and the mixture held at a constant temperature of about 200 deg. fahr. The tests were made on round pieces ($1\frac{1}{2}$ in. in diameter and 3 in. long) of chrome steel with approximately one per cent carbon and 1.50 per cent chromium.

As the object was to determine the lasting effect of the pickling on the metal, various subsequent treatments were used in order to neutralize fully or partly the effect of the pickling, the pieces being washed in cold, hot or lime water and tested either immediately or after periods varying from 7 to 28 days. The tests were made for hardness without cleaning, polishing or filing the surfaces in any way previous to the test, this being done in order to avoid the possible removal of a skin which might have appeared as a result of the pickling.

On the whole, it was found that the hardness results do not seem to be affected by the pickling treatment, although there was a slight indication that the unpickled steel has a somewhat softer surface than the pickled specimens.

Careful machining tests showed absolutely no difference in machinability, and it would appear that pickling affects only the skin, and even that to an effect not noticeable in machining.

Further tests were made to find out, if possible, whether pickling would have any effect upon the surface of the material and whether this effect were traceable to any appreciable depth. In these tests each piece of steel was subjected to a careful microscopic examination of the surface before and after aging and at various magnifications. The photomicrographs do not show any distinct difference between the pickled and unpickled bars.

The general conclusion drawn from these tests is that pickling in itself, as well as pickling followed by various treatments, does not interfere in any noticeable way with the quality or machinability of the steel. (*Iron Age*, vol. 105, no. 9, Feb. 26, 1920, pp. 593-594, 6 figs., *e*)

FOUNDRY

Howe Suspended Molding Machine

Suspended Molding Machine. Description of the installation and use of suspended molding machines at the works of the Standard Malleable Iron Company, Muskegon Heights, Mich., where it is claimed that their use effected an increase of production per molder of from 15 to 30 per cent, depending on the class of work done.

The machine hangs on a rail which extends lengthwise over the milling floor and is easily movable from place to place. It is equipped with pneumatically controlled legs (Fig. 4) by which it can be held firmly in a stationary position regardless of the irregularities of the floor. These legs are in reality plungers fitted in pneumatic cylinders and are controlled by a stopcock.

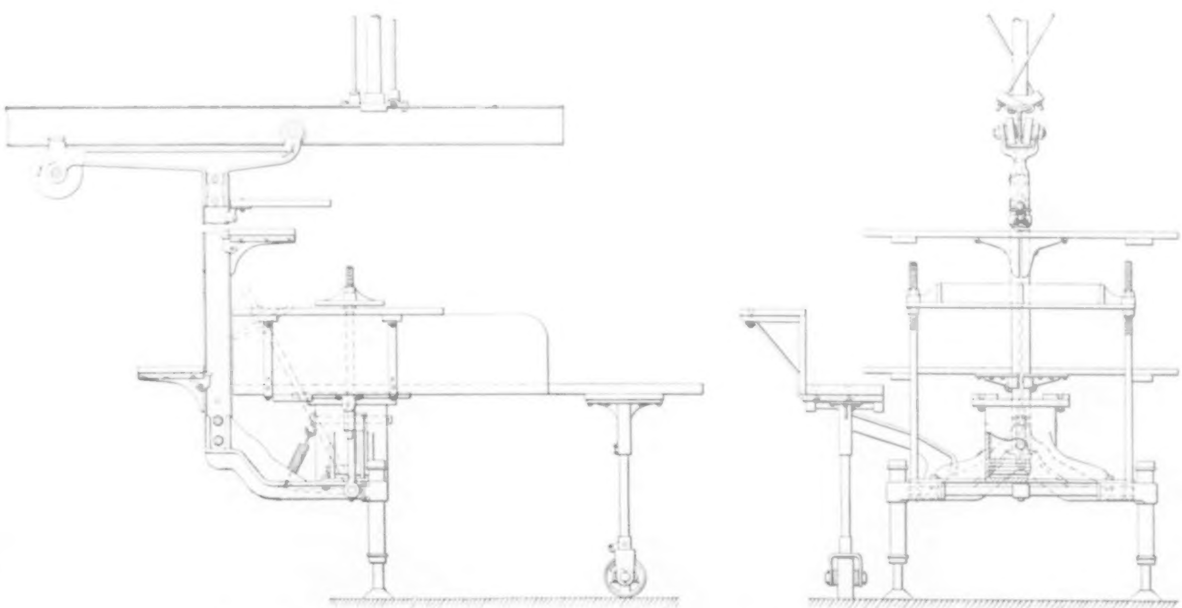


Fig. 4 Howe Suspended Molding Machine with Squeezer Attachment

In its simplest form the machine is really a movable molding bench. With benches fixed at the walls, the molder was forced to carry his work over the floor to the aisle, running the risk of shifting the molds. The suspended bench enables him to commence work close to the aisle near his sand pile and gradually move toward the wall as his day's work progresses. The machine also enables the molder to handle all his own molds, even such where ordinarily a helper would be needed to carry them out.

Another advantage of this device is that the molder's afternoon work is not interfered with by the heat radiating from the hot sand dumped from the morning molds.

It is claimed that the machine facilitates the use of a sand cutter. The sand is dumped from the flasks in a pile extending from the aisle to the wall parallel with the course of the molding machine. At the close of molding operations for the day, the sand machine cuts the sand in each pile in the foundry. It moves from aisle to wall and back in the brief space of $1\frac{1}{2}$ min. as compared with 30 min. of hand labor employing several men.

Each of the molding benches is equipped with adjustable shelves and a long side bench, the latter being attached to the machine by a bracket and supported on a wheel. (*Iron Age*, vol. 105, no. 10, Mar. 4, 1920, pp. 665-666, 3 figs., *d*)

FUELS (See Railroad Engineering)

HANDLING OF MATERIALS (See Power Plants)

HEAT TREATING (See Machine Shop)

INTERNAL-COMBUSTION ENGINES (See also Aeronautics and Physics)

Single-Sleeve-Valve Engine with Outside Sleeves

Melton-Haury Engine. Description of a new engine, known as the Melton-Haury, whose characteristic feature is the single sleeve located outside of the cylinder, which means that the usual amount of water-cooling area is available.

The single-sleeve valve (Fig. 5 on the following page) is a cylindrical structure with port openings of large area. This cylindrical structure is split longitudinally and must be sealed in that direction. This is accomplished by a dovetailed edge that effectively seals the joint.

The cylinders are removable and are machined inside in the same manner as poppet-valve engines, giving also a minimum of friction surface on the outside, the valves traveling against this outside surface with the bearing surface integral with the block.

The valves are positively operated by individual valve shafts driven by helical gears, these shafts being located directly below the driving lug on the sleeves in order to reduce any side thrust or undue strains.

The construction is of interest because it permits the cylinder to be well cooled while the sleeve valve is amply lubricated. On the exhaust side, the exhaust manifold is provided with hot points protruding downward into the intake manifold against which the carburetor is attached. The gases, being preheated, pass through the block between the cylinders into the distributing manifold inside of the engine block. (*Commercial Car Journal*, vol. 18, no. 6, Feb. 15, 1920, pp. 23-24, 3 figs., *d*)

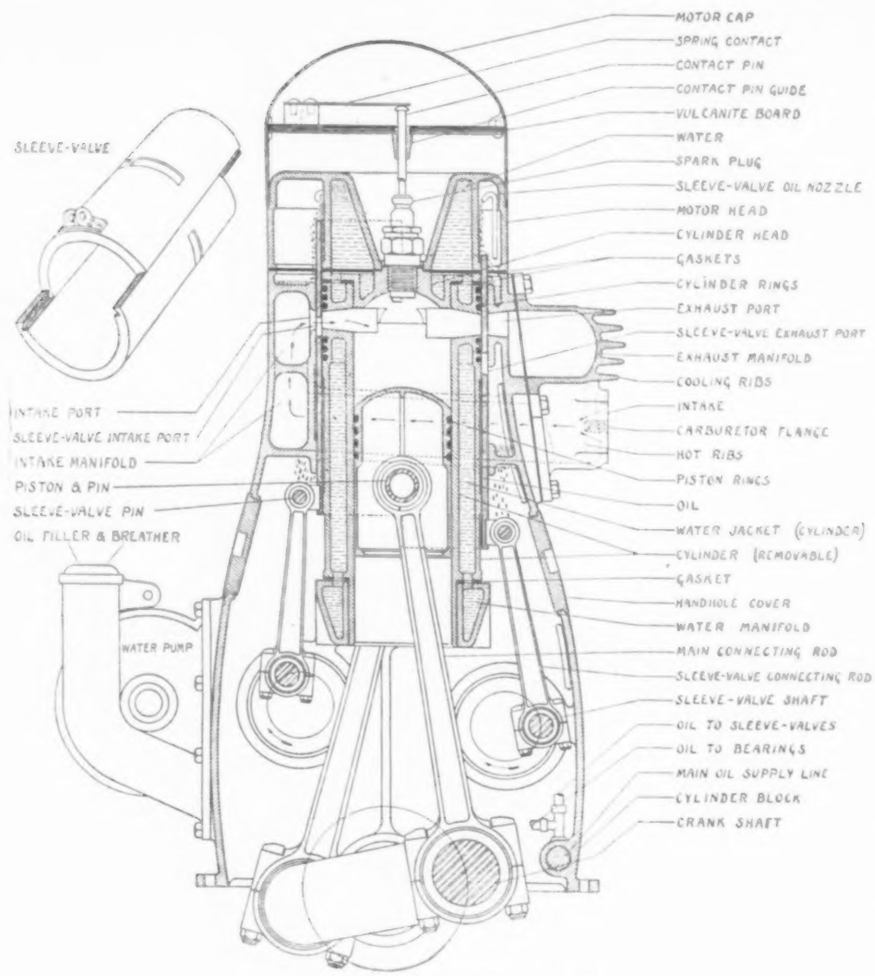


FIG. 5 MELTON-HAURY ENGINE

MACHINE SHOP

Design and Materials for Pots and Boxes Used in Carbonizing; Heat-Resisting Alloys; Q-Alloy of Nickel-Chromium Family

POTS AND BOXES USED IN CARBONIZING, H. H. Harris. While heat-treating furnaces and processes have been consistently developed in the last score of years the pots and boxes used in the cyanide and lead-hardening processes have changed very little.

Three factors govern the service received from carbonizing pots and boxes, namely, design, method of manufacture, and material. As regards design, the author states that while in some plants there have been considerable improvements, through the industry at large a great majority of carbonizing boxes are of a design as well adapted for packing soap in as they are for carbonizing, which affects the results obtained in a very undesirable manner.

To be good a box must be designed to permit tight sealing with some refractory or other material, in such a manner, however, that the clay should not enter the box and mix with the compound.

Proper dimensions of the box are also important. The thickness of the box should be as thin as possible in order to prevent warpage and still sufficient to permit proper flow of metal in the casting.

Materials for pot and box manufacture may be grouped into six classifications: cast iron, cast steel, pressed and rolled steel, "trick" materials, alloys and materials calorized.

Cast iron is both the cheapest first-cost material and the poorest. It oxidizes rapidly, gives a non-uniform service, becomes distorted easily, forms scale which mixes with the carbonizing compound and is likely to spoil the work, and finally is affected by the cyaniding mixtures.

Cast steel is generally much superior to cast iron. It costs about twice as much per pound, but may give much longer service. The principal objection to cast steel is that the grade of steel used for pots and boxes is usually of inferior quality, sometimes even semi-steel being offered for steel. The method of casting the pots and boxes is also often unsatisfactory.

Judging, however, from the average of various types and conditions studied in many of the largest plants in the country, the author does not believe that any material has shown on the average a uniformly longer life per dollar invested than cast steel, with the exception of a nickel-chromium alloy which he refers to as "Q-alloy."

Pressed- and wrought-steel pots were quite generally used some time ago before the advance in price of this material. Its advantage is its light weight and consequent small heat consumption. Its disadvantages are its high price and the comparatively few shapes in which it can be secured. Some companies manufacture their own annealing boxes from wrought steel, riveting or welding them together. Some of these are said to give satisfaction in extreme temperatures, but not under general conditions. Wrought-steel riveted or welded pots for cyanide, chloride or lead conditions have never been successful owing to leakage.

By "trick" materials, the author means products misrepresented by their makers or sold under a trade name which does not correctly indicate their nature. Alloys for heat-resisting purposes are a new development and may be said to be still in their infancy. At this time there are more than 35 patents covering heat-resisting alloys.

The latest development in the alloy field is a special nickel-chromium alloy, the analysis of which the author is not yet authorized to divulge. This material differs from nickel-chromium alloys on the market in that it retains many of the physical characteristics of the cold metal at a temperature of 2800 deg. fahr. and rings like a bell when struck with a hammer at this temperature. This new alloy is known as Q-alloy, grade X.

The only true scale of value by which a user can judge most competitive production materials consumed in service is by comparing their life under service conditions with their initial cost, and determining how many units of service each renders per dollar investment. In computing pot and box cost a unit is a heat-hour, which is an hour in the furnace under heat. Cost per heat-hour is arrived at by dividing the number of heat-hours received into the initial cost of the pot or box; for instance, if a cast-iron box weighing 100 lb. and cost 5 cents per lb. runs 100 heat-hours, the cost is 5 cents per hour. A steel box at 12 cents per lb. should run at least 300 hours under the same conditions, making a cost to the user of 4 cents per heat-hour. Under certain circumstances parallel to this Q-alloy has been known to run 7000 hours, making a cost to the user of 2 cents per heat-hour. Where an alloy affords a saving in cost per heat-hour it minimizes warpage and allows a thinner section to be used, thereby saving fuel in heating the box and its contents.

Thousands of tons of metal per annum are being consumed in the fires of heat-treating furnaces. This metal is paid for by companies every one of which could use the money so expended to the betterment of their product rather than writing it off in the profit-and-loss column and passing the tariff on to the ultimate consumer. American industry quite frequently puts up with undue waste to obtain production and perhaps the greatest

waste in the metal-working industries, which can be directly attributed to ignorance and neglect, is the waste of metal consumed in the heat-treating processes. This waste can never be entirely eliminated, but it may be greatly reduced. (*The Iron Age*, vol. 105, no. 11, Mar. 11, 1920, pp. 729-731, *de*)

MACHINE PARTS

A NEW NUT LOCK. A new form of locking washer for bolts and nuts has just been brought out by the Palnut Company, Limited, of 6 Great St. Helens, London, E. C. 3, and, although we have not yet had an opportunity of testing its efficacy thoroughly, the principles on which it is designed appear to us to be sound. The washer is a simple stamping which takes the form of an inverted dish, with the edge turned up in such a way as to make a hexagonal rim. The center of the dish is pierced for the passage of the bolt, and there are half a dozen radial slots which divide the dish up into sector-like teeth connected together round the rim. The teeth are so stamped that when the washer lies on the top of a nut their apices follow the contour and project well into a single thread on the bolt. All that is necessary to put the washer in action is to screw it down tight above the nut to be locked. There is a natural tendency for the dish to flatten out when it comes into contact with the nut when forced down by a spanner. As the sector-shaped teeth cannot expand outward during the flattening process, they dig inward into the thread of the bolt, and thus obtain, so it is claimed, a very secure hold. On the other hand, if the nut tends to slack back, it will produce the same flattening effect, and the grip of the washer will be increased so long as it does not turn with the nut. In order to prevent that happening, that part of the washer which beds on the nut is formed with a smooth, rounded surface, with the object of insuring that the friction between the nut and washer shall be reduced to a minimum. The washer can, of course, easily be removed by means of a spanner. There is just one little matter in which we think that the washer might be improved. It is that it should be stamped plainly with the word top, or some other indication as to which way up it is to be used. The device would be valueless if put on the bolt upside down, and the perverseness of mechanics in the use of lock nuts is proverbial. (*The Engineer*, vol. 129, no. 3343, Jan. 23, 1920, p. 102, *d*)

MACHINE TOOLS

Multiple-Way Drilling Machines, Heavy-Duty Type, with Chip-Protection Device on Inverted Head

THE FOOTE-BURT "WAY" DRILLING MACHINES, J. V. Hunter. Multiple-way drilling machines are a comparatively recent development. The early types had a single vertical column supporting the work jig on which ways were planed for the travel of the saddles of both the upper and inverted drilling heads. The side heads were carried by comparatively light wing brackets bolted to each side of the column, which gave the machine a somewhat spidery appearance. About 1912-1913 these machines were improved and built more substantially. Among other things, the numerous individual oil cups of the older type were supplanted by gang sight-feed oilers with feed pipes to the various bearings; and a year or two later a provision was introduced tc avoid the troubles caused by chips and dirt which work into the bearings of the inverted spindle head.

This head (Fig. 6) is now protected at the top by a sloping shield *A*, which tightly surrounds the spindle and prevents the accumulation of chips.

Below the shield are two plates, *B* and *C*, spaced a fraction of an inch apart where they surround the spindles and bolted together with an airtight flange around the outer edges. At each end of these plates is an air-hose connection; from one of these a blast of air can be blown, the exhaust taking place through the other, and all fine dust which enters this place is blown out, thus preventing its reaching the inner bearings. In addition to this each spindle is surrounded by a tapered cone *D*, which fits over a stationary sleeve *E* that extends through the top shield to the plate *B*. The sleeve *E* is stationary, so no wear occurs between it and the shield.

The appearance of the latest model of a four-way drilling machine is shown in Fig. 7. Here the base is wide and heavy, supporting a full-width column of such proportions that no side arms are required. The single oil pump in the base handles practically the entire oiling.

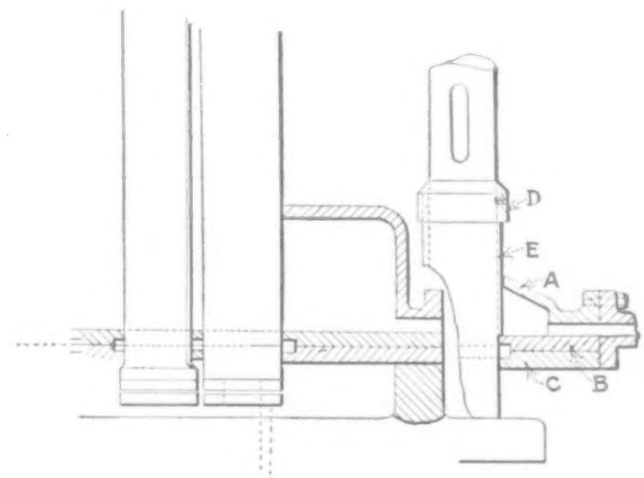


FIG. 6 CHIP-PROTECTION DEVICE USED ON INVERTED HEAD OF THE FOOTE-BURT MULTIPLE-WAY DRILLING MACHINE

In addition to this, drill levers *A* (Fig. 7) automatically reverse the feed to draw out the drills rapidly on the completion of their cut.

One of the latest machines carries 61 active spindles. In addition to the four-way there is a three-way drilling machine, such as would be necessary for drilling the automobile-engine oil pan. It is simpler than the four-way machine because of the absence of the inverted spindle head, but does not materially differ from it otherwise. (*American Machinist*, vol. 52, no. 10, March 4, 1920, pp. 485-487, 8 figs., *d*)

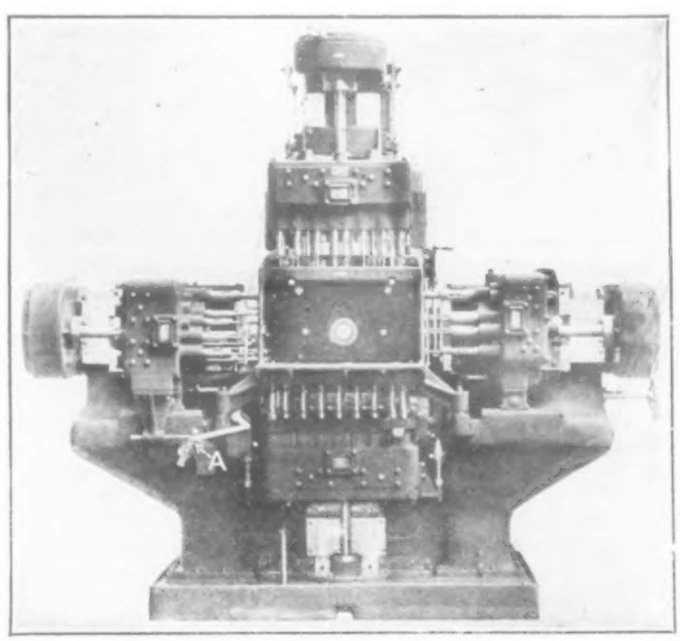


FIG. 7 LATEST MODEL OF FOOTE-BURT FOUR-WAY DRILLING MACHINE

MANAGEMENT

Fatigue, Its Character and Forms; Tiredness; Fatigue and Accidents

FATIGUE AND ITS EFFECT ON PRODUCTION, A. Vautrin. Discussion of the nature of fatigue, its forms and degrees, and its influence on productivity of labor, accidents, etc. The distinction is established between fatigue as an objective phenomenon and the subjective feeling of fatigue, or tiredness.

It has been known for some time and experimentally established by Kraeplin that all work done by man, whether physical or mental, is accompanied by a series of reactions which either favor its continuation or oppose it. The most important of the reactions opposing the tendency to continue working is known as fatigue, and may be of a physical or mental character or a combination of the two.

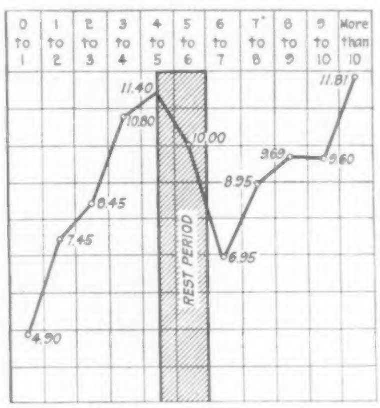


FIG. 8 DISTRIBUTION OF ACCIDENTS IN THE CHEMICAL INDUSTRY DURING THE WORKING DAY IN THE YEARS 1897-1907

Hours Worked and Percentage of Employees Injured During Each Hour

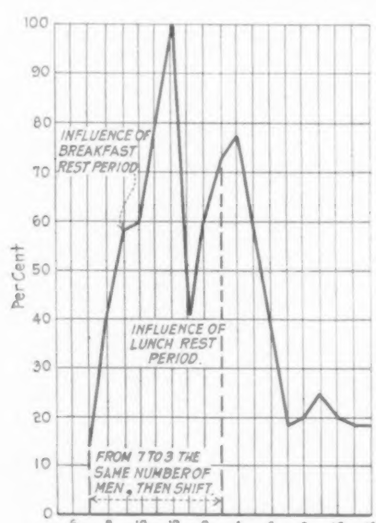


FIG. 9 DISTRIBUTION OF ACCIDENTS IN A GERMAN CABLE FACTORY THROUGHOUT THE WORKING DAY

As regards its physical nature, it appears that all work produces in the body substances (chemical or organic) which exert gradually a narcotic effect on the central organs of the nervous system. In fact, Weichhardt claims to have found present in animals a poison produced by fatigue which he calls kenotoxin.

Fatigue may be either physical or mental. In physical work certain groups of muscles are set in action, thereby producing a corresponding excitation in the central nervous system. Muscular fatigue takes place, therefore, partly on the muscular periphery and partly at the brain center, and the more demand is made on the brain center, the greater the final fatigue. Purely mental work creates a demand on the large brain, which means a gradual exhaustion of the gray matter and a certain demand on the nervous ganglia connected therewith. In either case, however, sooner or later exhaustion of the organs brought into action follows.

Moreover, there is a close connection between physical and mental fatigue, and it is a well-known fact that when the body is overtired for any considerable length of time, this also reduces the ability of the brain to do mental work. The reason for this is clear. All work may be physiologically considered as a process of consumption which calls into play not only the organs directly producing the work, but, more or less, all the energy reserves of the body. Hence bodily exhaustion will gradually lead also to mental exhaustion, and an overburdening of one part of the body by products of fatigue will necessarily sooner or later affect the operating ability of all the other parts of the body.

Fatigue is only a moderate degree of the lowering of the producing ability of the body due to exhaustive work. A greater degree thereof is known as exhaustion, and the difference between the two is stated as follows: Fatigue leads to the lowering of the ability to perform work; exhaustion represents a state at which the performance of work becomes entirely impossible. Physiologically, exhaustion represents such an accumulation of the products of fatigue that the body is unable to reconstruct itself for the time being.

A clear difference must be made between fatigue, which is an objective phenomenon and represents the actual failing in the ability to perform work, and the subjective feeling of fatigue, namely, tiredness. Whereas fatigue is produced by the actual physiological processes of exchange of materials in the body, tiredness may be the result of various conditions and circumstances often lying entirely outside of the effort to produce work. Fatigue is a physiological phenomenon; tiredness, psychological. It may be due to lack of interest in the work performed, outside happenings in the life of the workman, etc.

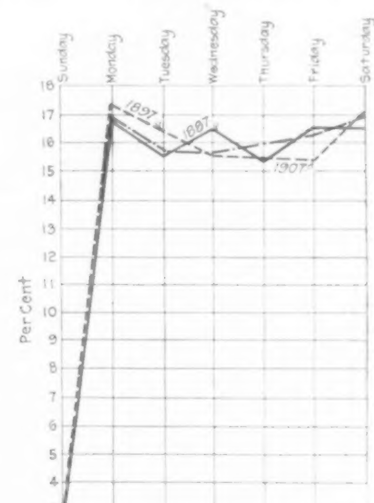


FIG. 10 FREQUENCY OF ACCIDENTS IN THE VARIOUS DAYS OF THE WEEK COMPUTED PER 100 INJURED OR KILLED PERSONS

The degree of tiredness depends mainly on the condition of the workman, and the same amount of effort will produce a greater tiredness in a weak man than in a strong man, in a man poorly nourished than in one well nourished, and in boys and women than in grown-up men.

Fatigue and Accidents. The paper presents a number of facts in confirmation of the claim often brought out before that there is a distinct connection between fatigue and accidents, although the author makes it clear that he does not consider accidents as being due to fatigue exclusively.

From his data it would appear that in the hours when the

fatigue of the workman is still slight there are scarcely any accidents, while in the sections of the working day or week, when the fatigue has grown to an appreciable extent, the number of accidents is more than double the average. Figs. 8 to 10, together with tabular data in the article, would indicate that interruption of the working day by rest periods reduces accidents very materially, and that of all the days of the week, Saturday, the day when fatigue is at its climax, is the worst day from the point of view of accident occurrence. This is particularly apparent in plants which do not employ the Saturday half-holiday.

The following statistics were collected in Lower Frankonia in 1895:

Length of working day, hours	9½	10½	13	over 13
Accidents per 100 workmen	1.1	2.0	13.2	17.0

In printing establishments the accidents for the years 1910 to 1913 were on an average distributed in the following manner throughout the days of the week:

Sunday	136	Thursday	543
Monday	535	Friday	580
Tuesday	583	Saturday	585
Wednesday	530		

(*Technik und Wirtschaft*, published by the Verein deutscher Ingenieure, vol. 12, no. 11, Nov. 1919, pp. 748-758, 3 figs., *g*)

MARINE ENGINEERING

Concrete Ships Still an Experiment, Reports American Concrete Institute

Present Status of the Concrete Ship. The original program of concrete-ship construction of the Emergency Fleet Corporation was reduced after the armistice to a total of fourteen vessels, and in October 1919 contracts for two 7500-ton cargo vessels were cancelled.

At the present date there are in service three 3500-ton cargo vessels and one 3000-ton cargo vessel, three 7500-ton tankers and twenty-one 500-ton canal barges built by the Railroad Administration under the supervision of the Emergency Fleet Corporation. The remaining vessels are in various stages of completion and are expected to be in commission by next summer.

In general, it is stated that in carrying out this program no construction problems were encountered which were not successfully met. The experience of the vessels in service thus far indicates that for cargo vessels there is ample structural strength, and that the barge is a much simpler problem in concrete than in usual materials.

On the other hand, it was not found that reinforced-concrete hulls could be built with greater speed than steel hulls, the average time of constructing the concrete hull being seven months.

In service concrete ships stood up quite well. In fact, there is generally less vibration in concrete ships than in corresponding steel ships, and also a considerable increase in the period of roll, which is desirable and is apparently due to the fact that these vessels have a larger moment of inertia around longitudinal axis than steel ships, due again to the mass of the concrete shell being considerably greater than the mass of the shell in a steel ship.

On the other hand, experience seems to indicate that these vessels are unable to withstand severe concentrated blows on the shell without the shattering of the concrete.

Impact, which in the case of a steel ship would probably only cause indentation to the plates, in the case of the concrete ship is apt to cause a shattering of the concrete over the area adjacent to the point of impact.

Repairs, especially in the case of barges, are, however, relatively simple and can be effected with little loss of time and at small cost.

The dead-weight capacity of the concrete ship was found to be lower than expected, the ratio of dead-weight capacity to displacement being on the average little more than 0.50. Furthermore, in the case of a steel ship and a concrete ship having the same dead-weight capacities, the concrete ship because of the greater weight of the ship itself must have greater dimensions than the steel ship, and in consequence must have greater hold spaces. For heavy-weight cargoes such as steel, coal or oil, in which the dead-weight capacity is reached before the hold spaces are filled, steel has obviously an advantage over concrete as a material of construction, assuming that construction and operating costs are equal. For bulky cargoes, such as ordinary goods, cotton, fruit or other materials for which the space required exceeds about 70 cu. ft. to the ton, the concrete ship will actually carry more dead weight than the steel ship for the reason that the hold spaces of the steel ship will be filled before dead-weight capacity is reached.

The report expresses the opinion that no definite conclusions should be drawn as yet from the experience of these vessels; and that the only general conclusion therefrom seems to be that it is possible to construct ships of concrete in about the same time, and for approximately the same cost as corresponding steel ships, which would indicate that with more experience in the art it will be possible to reduce both the cost and the time for construction. As regards the length of life of concrete ships, no sufficient data are available, and the brief experience of vessels afloat has disclosed no serious inherent weakness to shorten the life of a concrete ship. (Report read at the Convention of the American Concrete Institute, at Chicago, Feb. 16-18, 1920, by Committee on Reinforced Concrete Barges and Ships, H. C. Turner, Chairman. Abstracted through *Engineering News-Record*, vol. 84, no. 10, Mar. 4, 1920, pp. 463-464, *g*)

PHYSICS

Rate of Propagation of Flame in Mixtures of Methane and Air; Photographic Analysis of the Flame; Detonation Wave

The Propagation of Flame in Mixtures of Methane and Air, Pt. I—Horizontal Propagation, Walter Mason and Richard Vernon Wheeler. In a previous paper the authors discussed the initial "uniform movement" of flame in gaseous mixtures. The uniform movement, however, is only one phase in the propagation of flame and is of comparatively short duration. The speeds attained by the flame during its régime are slow compared with the speeds during other phases in the propagation of flames in mixtures wherein no detonation wave has developed.

A knowledge of the speeds of flame in such mixtures as methane and air is of considerable importance, for example, in connection with the safe working of coal mines and also indirectly for internal-combustion-engine design.

The present paper describes experiments relating to phases other than the uniform movement during the horizontal propagation of flame in mixtures of methane and air. The experiments were carried out in tubes of different dimensions and materials, measurements of speeds having been made by the "screen wire" method. Supplementary information was obtained by photographic analysis of the flames.

The experiments were carried out first on ignition at the open end of a tube closed at the other end; next, ignition at the closed end of a tube open at the other end; and finally, ignition at one end of a tube open at both ends.

Taking the case of ignition at the open end of a tube closed at the other end, the initial phase of propagation of flame constitutes the "uniform movement."

The linear duration of this phase is controlled by such factors as influence the establishment of resonance in the column of gases in the tube, among these being the speed of the flame and hence the composition of the inflammable mixture, length, diameter and uniformity of bore of tube. Eventually, as a direct outcome of the establishment of resonance, the flame front acquires a periodic undulatory motion, leading sooner or later to violent vibrations which vary considerably in amplitude but remain periodic.

During the vibratory movement the oscillations of the flame are of wide amplitude and the mean speed of translation of volume is considerably enhanced.

The vibratory movement is also an excellent example of the effect of agitation or turbulence in accelerating the translation of flame through a gaseous mixture. The effect is a mechanical one. During each forward impulse the flame is drawn rapidly through previously unburned mixture by reason of the motion acquired by the resonating column of gases. In a certain degree also the forward motion of the flame is assisted by the expansion in volume of the burning gases, especially when the flame is at some distance from the open end of the tube, so that the escape of the expanded gases there is retarded.

The two other cases are discussed in the same manner. The most important one probably is that of ignition at one end of a tube open at both ends.

In that case it was found that the speed of the flame in all mixtures except the limit mixtures increases continuously over the whole distance traveled, and it seemed possible that the detonation wave might be developed if the flame could travel far enough.

In tests with a steel tube 15.25-m. long, it was found that the flame had acquired a vibratory character after traveling over the length of the tube. The length of the tube was then increased to 30 m. in the expectation that a greatly increased distance of travel would produce regular recognizable vibrations of large amplitude. The results confirmed this expectation. The propagation ultimately become strongly vibratory, but the early stages of the propagation were deeply modified by the increased length given to the tube. Instead of increasing rapidly in speed from the beginning as with the shorter tube, the flames now travel from the point of ignition at a constant and comparatively slow speed over a distance of between 12 and 15 m. and then began to vibrate. The vibrations acquired their greatest amplitude about half way along the tube (as was the case with the shorter tube) and continued throughout the remaining distance.

Of these three conditions under which the ignition of mixtures of methane and air has been effected, the one which would appear to lead to the most disastrous results in industry is the third, that is, ignition at one end of a tube or gallery open at both ends.

The fastest speed of flame acquired in any experiment was about 60 m. per sec. and was of short duration. The experiments have not, however, shown that a detonation wave cannot be developed in mixtures of methane and air at normal temperatures and pressure. On the contrary, the experiments with the long steel tube indicated that such an eventuality is possible. (*Journal of the Chemical Society*, vols. 117 & 118, no. 687, Jan. 1920, pp. 36-47, 2 figs. in text and 3 plates, *eA*)

The Propagation of Flame in Complex Gaseous Mixtures, Wm. Payman. It is customary to describe the inflammation of a gas mixture containing, for example, hydrogen and oxygen as the "burning of hydrogen in oxygen." This phrase is purely a relative one, and it is equally correct to regard the combustion as the burning of oxygen in hydrogen. Thus, the upper limit of inflammability of hydrogen in oxygen is the lower limit of inflammability of oxygen in hydrogen.

Mixtures of a combustible gas with air can be considered in a similar way and burning of hydrogen in air may be considered as burning of oxygen in a mixture of nitrogen and hydrogen.

For purposes of thoroughly investigating the mode of combustion of complex inflammable gas mixtures, it is desirable to examine their behavior with "atmospheres" other than air, the simplest problem being the combustion of a pure inflammable gas such as methane in pure oxygen.

The present research deals, therefore, with mixtures containing more oxygen than air and with mixtures with pure oxygen, the subject under investigation being mainly the initial uniform movement of flame which is supposed to be mainly effected by the conduction of heat from the burning to the adjacent unburned layer of gas mixture as different from what is known as "detonation wave."

If we neglect losses of heat to the walls of the containing vessel, the speed of propagation of flame during the uniform movement can be regarded as depending mainly on two factors, namely, (1) the rate of conduction of heat from layer to layer of the mixture, which in turn depends on the difference in temperature of the burning and the unburned gases and on their thermal conductivities, and (2) the rate of reaction of the combining gases, which for a given combustible gas will vary with the composition of the mixtures (presumably according to the usual laws of mass action) and with the temperature produced by the reaction. A third factor might be added, namely, the ignition temperature of the mixtures, but this is perhaps dependent on the other factors.

The mixture of hydrogen and air for complete combustion, that is to say, the mixture having the greatest heat of combustion, contains 29.6 per cent of hydrogen, but the mixture in which the speed of the uniform movement of flame is greatest contains about 38 per cent, or nearly 10 per cent in excess.

Two series of determination of the speed of the uniform movement of flame in mixtures of oxygen with an atmosphere of nitrogen and methane and one of nitrogen and hydrogen have indicated that a displacement of the maximum speed mixture is toward mixtures containing an excess of oxygen. Further tests with combustible gases burning in air have shown that the addi-

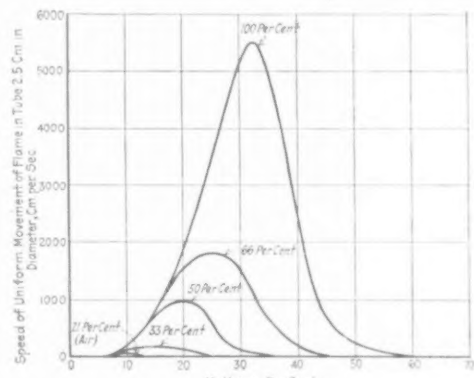


Fig. 11 Curves of Speeds of Uniform Movement of Flame in Various Mixtures of Methane and "Atmospheres"

tion of either combustible gas or oxygen to the basic mixture results in an increase in speed of the flame; and furthermore, in accordance with the laws of mass action, the displacement is greater on the addition of oxygen than on the addition of methane, due to the fact that the combination of one molecule of methane with two molecules of oxygen results in complete combustion. On the other hand, the displacement, according to the same laws, should be less with the oxygen than with hydrogen since two molecules of hydrogen combine with one molecule of oxygen, and experiment shows this deduction to be correct.

The speeds of uniform movement of flame in mixtures of methane with atmospheres containing 13.7, 22, 33, 50, 66 and 100 per cent of oxygen have been determined, some by means of an automatic commutator and single recording stylus, some by delicate Deprez indicators and the fastest speeds photographically. The results of the determinations are given in tables and also in Fig. 11.

The most striking results are those for mixtures of methane with pure oxygen. Here the maximum speed of the uniform movement of flame is attained with the mixture containing methane and oxygen in combining proportions ($CH_4 + 2O_2$). The result is a sharp distinction from what obtains when the detonation wave is developed in mixtures of methane and oxygen, for the mixture in which the speed of the detonation wave is greatest contains equal proportions of methane and oxygen.

The retarding effect of addition of methane to the mixture for complete combustion ($CH_4 + 2O_2$) is well illustrated by photographs given in the original article. In such a case, either methane or oxygen acts exactly like an inert gas, such as nitrogen, and in fact, methane, having the highest specific heat of the three, has the greatest retarding effect.

In the latter part of the article the writer gives the method of

calculating mixtures so as to obtain given uniform speeds of flame movement. (*Journal of the Chemical Society*, vols. 117 & 118, no. 687, Jan. 1920, pp. 48-58, 6 figs., *eA*)

POWER PLANTS

Ash- and Coal-Handling Equipment

ASH- AND COAL-HANDLING EQUIPMENT, W. O. Rogers. In an article entitled Power Drives for Rolling Mills, the writer describes an interesting system of ash- and coal-handling equipment installed at the new power plant of the Republic Iron and Steel Company at Youngstown, Ohio. Ashes from the stokers of the boilers are deposited in an individual three-outlet iron ash hopper lined with red brick. The outlet of the ash hopper is provided with gates (Fig. 12) operated on rollers and actuated pneumatically by a plunger controlled by a four-way valve. The ashes

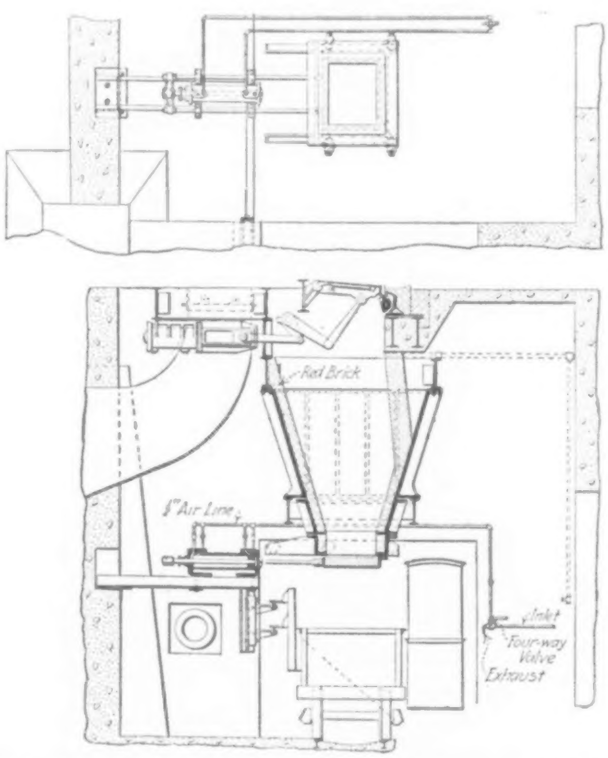


FIG. 12 ASH HOPPER AND ASH GATES AT THE ROLLING-MILL POWER PLANT OF THE REPUBLIC IRON AND STEEL COMPANY, YOUNGSTOWN, OHIO

are dumped into motor-operated cars having a capacity of 50 cu. ft. The loaded car is run to a hopper from which the ashes have elevated to the top of the hoist and automatically dumped into a chute leading to a bin from which they are loaded into railroad cars for removal.

The operation of the ash hoists is of interest. When the ash handler desires to elevate a load of ashes that has been dumped into the hopper, he presses a starting switch to start the 50-hp. d.c. motor. When the 70-cu. ft. capacity skip nears the top, a resistance coil is cut in on the circuit, which causes the motor to slow down. When the ash bucket reaches the dumping position, the circuit is automatically cut and the bucket stops long enough to discharge its contents. By means of a relay switch on the control board, after the bucket has remained at the dumping position a sufficient length of time to dump, the current is automatically applied to the motor, which has been reversed by means of a limit switch, and the bucket is sent to its original loading position ready to receive another load. The cycle comprises a period of 2½ minutes.

Coal is delivered from railroad cars into a rack hopper, from which it is conveyed to the crusher by means of an apron-type conveyor 65 ft. long, center to center, and 36 in. wide. This conveyor has a capacity of 180 tons per hour at a speed of 40 ft. per min. Power to operate it is taken from the crusher shaft transmission by means of a chain drive to the hoist countershaft of the conveyor drive.

The crusher is of the four-roll type, each roll being 36 in. in diameter and 36 in. face. One pair of rolls is held rigidly in position, while the other pair is provided with heavy coil springs strong enough to press the coal and yet permitting of giving in case a foreign substance is encountered. The rolls and apron conveyor are operated by a 100-hp. compound-wound motor at 850 r.p.m. The capacity of the crusher, with run-of-mine bituminous coal crushing to 90 per cent ¾-in. size, is 180 tons per hour.

The article contains also a description of the boiler house and furnaces with their stokers. (*Power*, vol. 51, no. 8, Feb. 24, 1920, pp. 291-296, 5 figs., *d*)

Tests of Canadian Fuels; Distribution of Heat Losses; Factors Affecting Efficiency of Boiler Furnaces

RESULTS OF 41 STEAMING TESTS CONDUCTED AT THE FUEL-TESTING STATION, OTTAWA. The paper gives results made on tests with Canadian coals and as such is mainly of local interest. Some remarks are, however, of general interest and are reported here.

The tests were conducted in a Babcock & Wilcox water-tube boiler having 677 sq. ft. of heating surface. Some of the tests were conducted on a grate area of 23 sq. ft. with an air space of ¼ in. between the bars; others on a grate area of 21 sq. ft. with an air space of ½ in. between the bars.

As regards losses, the following remarks are found in the report. The principal heat loss was that due to the total heat of the flue gases, which, in this case, does not include that due to the uncondensed steam. The variation of the loss due to the escaping hot gases for approximately the same boiler output is due almost entirely to the change in the amount of excess air. A figure is introduced showing the relation between the ratio of the flue-gas total heat loss to the heat usefully employed for steam raising and the ratio of the total air supplied to the air whose oxygen content is combined with the fuel (this relation is expressed as a straight line). This air ratio is calculated from the flue-gas analysis, and is equal to $\dfrac{21}{21 - O_2 \dfrac{79}{N_2}}$ where O_2 and N_2 represent the volumes of oxygen and nitrogen in the flue gas, and $\dfrac{21}{79}$ the ratio of oxygen to nitrogen in the atmosphere. The expression $\dfrac{21}{100}\left(\dfrac{100 + XL}{X\,(1 + L)}\right)$ represents the ratio of air supplied to air required in terms of the carbon dioxide content of the flue gas (X) and the factor L, which depends upon the chemical constitution of the coal, and is equal to $\dfrac{3}{C}\left(\ H - \dfrac{O}{8}\ \right)$, where H, O, and C represent the relative weights of the hydrogen, oxygen, and carbon contents of the fuel. This expression holds good only for complete combustion of a fuel whose sole constituents—which pass off with the flue gas—are carbon, hydrogen and oxygen.

As regards the variation in excess air, it is found that the air ratio was less when using a grate of 21 sq. ft. area with ½-in. air spaces than when using a grate of 23 sq. ft. area and ¼-in. air space for the same fuel, and approximately the same rate of steaming. On the other hand, it was found that the excess air increased with an increase of rate of combustion for the majority of coals.

While a change from the grate with small to one with larger air openings reduced the excess air loss, it was found that the loss due to unburned solid fuel increased for the trials with the

larger air space and that this loss tended to increase considerably with an increasing ash content.

Briefly then, burning coal on a grate with 1/4-in. air spaces, tends to cause the loss due to solid unburned carbonaceous material to be less and the loss due to the escape of flue gases to be greater than when using a grate with 1/2-in. air spaces.

The principal reasons for the variation in the radiation, and unaccounted-for loss, where the rate of steaming remains the same, are variations in the heat transmitted from the hot gases and incandescent fuel through the boiler setting, and in the variation of the undetermined combustible content of the products of combustion.

A number of figures are plotted in the original report showing the total loss due to radiation, unburned gases and the unaccounted-for loss. These figures are plotted on a base representing the ratio of the air supplied to that used for combustion. While no attempt has been made to plot a curve showing any general law, it would appear that the loss tends to decrease with an increased air supply.

An increase in the air-supply ratio may be expected, therefore, to be accompanied by a decrease in the loss due to incomplete combustion and by an increase in that due to the increased mass of gas escaping at a high temperature; and the efficiency of the boiler, based on the solid combustible consumed, will show the net result of the change.

In general, it would appear that the predominant effect of the increase in the air ratio for any particular fuel is to lower the efficiency, but this must not be considered in the light of an absolute law. (*Bulletin No. 27, Mines Branch, Department of Mines, Canada*, Ottawa, 1920, pp. 3-83, 41 charts, *eA*)

BOILER AND FURNACE TESTING, Rufus T. Strohm. Recommendations for simple tests of a particular character, the purpose of which is to find out how efficiently the boiler is working.

The test is of the nature of an evaporation test and comprises the determination of the total weight of coal used during the test, the duration of which is recommended as 8 hr.; the total weight of water fed to and evaporated by the boiler; the average temperature of the feedwater; the average steam pressure in the boiler.

The methods of determining these factors and simple formulæ for calculating results are given, as well as recommendations for using the results. (*Bureau of Mines Technical Paper* 240, reprint of Engineering Bulletin No. 1, U. S. Fuel Administration, Washington, 1920, *p*)

PUMPS

High-Vacuum Mercury Pump with Provision for Storing Gases Exhausted

HIGH-VACUUM MERCURY PUMP WITH PROVISION FOR THE PRESERVATION OF THE EXHAUSTED GASES, A. Beutell and P. Oberhoffer. Both mercury pumps of the Sprengel type and such mechanical pumps as the Gaede have the disadvantage of possessing no provision for conveniently collecting and preserving the gases exhausted from a high vacuum. This becomes of importance now that a considerable amount of interest has been aroused in the subject of gases occluded in minerals and metals. In the present article a pump is described with which it is possible to collect the gases exhausted from a high vacuum. It is stated that the new arrangement does not materially affect the rate of operation of the pump; thus, the 500-cc. container may be exhausted to a pressure of 0.0007 mm. in 10 min. and to a pressure of 0.00011 mm. in 20 min. Furthermore, if it is not desirable to collect the exhausted gases, the operation of the pump is not affected in any way.

As seen from Fig. 13, the pump is of the water-jet type, but the exhausted gases are not directed as usual into the water jet at *N*. Instead, there is inserted the small tank *E* between the downward tube *Fa* and the upward tube *St*, this container being equipped with a three-way cock. The upward tube *St* is provided at its lower end with an expanded section, the purpose of which is to prevent the flow of air from *L* into the container *E*. This made it necessary to increase the dimensions of the container *N*, the purpose of which is to take up the mercury displaced by the gas collected in *E*.

Because of this the amount of mercury used in the present pump is about 100 cc. as compared with about 20 cc. for similar pumps previously used and having no provision for the collection of exhausted gases.

Instead of the asbestos stopper formerly used for regulating the air admission at *L*, there is now welded in there a thick-walled capillary tube protected against penetration of dirt into it by another glass tube closed at one end. The three-way cock *N* at the top of the tube likewise employs a capillary tube instead of the normal asbestos stopper for the purpose of safely admitting air to the pump against the vacuum therein.

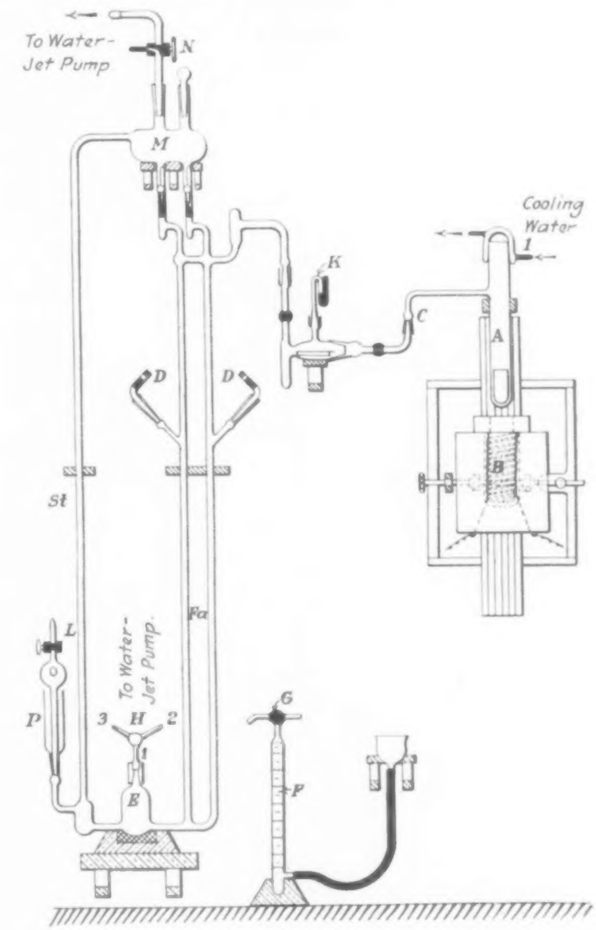


FIG. 13 BEUTELL AND OBERHOFFER HIGH-VACUUM PUMP WITH PROVISION FOR THE PRESERVATION OF EXHAUSTED GASES

The operation of the pump does not materially differ from that of similar pumps previously described. In addition, the article describes an apparatus for gas analysis. (*Chemiker-Zeitung*, vol 43, no. 125, Oct. 16, 1919, pp. 705-706, 4 figs., *d*)

RAILROAD ENGINEERING

Steam and Electric Propulsion for Railroads Compared; How the Railroads Utilize Their Fuel; Standardization of Frequencies; Electric Locomotives

THE LAST STAND OF THE RECIPROCATING STEAM ENGINE, A. H. Armstrong. By "the last stand of the reciprocating steam engine" the author, who is Chairman of the Electrification Committee, General Electric Company, refers to the steam operation of railroads.

In brief, he claims that where applicable the electric locomotive

is more reliable and more economical from the point of view of fuel consumption. He makes a reservation, however, to the effect that many roads of lean tonnage should not be immediately electrified, as they would render no adequate return upon the large capital investment required.

To illustrate the present situation he gives Table 1, showing the subdivision of the tonnage passing over the tracks of our railways (The source of the table is not indicated).

The first four items, representing nearly 85 per cent of the total ton-miles made during the year 1918, may be regarded as fundamentally common to both steam and electric operation. By introducing electric propulsion the last four items are considerably cut down, and it is claimed that approximately 12 per cent or about 150 billion ton-miles at present hauled by steam engines over the roads will be eliminated. This means that if *all* American railways were completely electrified they could carry one-fifth more revenue-producing freight tonnage with no change in present operating expenses or track congestion.

Another table would indicate that a quarter of all the coal mined in the United States is consumed by the railways, and the author claims that this is done with extreme wastefulness. This claim is based on tests made upon the Rocky Mountain Division of the C. M. & St. P. Ry. to determine the relation existing between the horsepower-hours of work done in moving trains and the coal and water consumed on the steam engines in service. From these tests it would appear that the total actual coal consumed under the engine boiler in 24 hr. divided by the actual work performed by the engine is equivalent to 10.18 lb. per hp-hr. at the driver rims. These tests have also shown that the coal consumed while doing useful work was raised 30 per cent by stand-by losses. In electrical constants this was found to be equivalent to 7.56 lb. of coal per kw-hr. at power supply on a basis of 55 per cent efficiency.

TABLE 1 TOTAL TON-MILE MOVEMENT
(All Railways in United States—Year, 1918)

	Per Cent	Ton-Miles
1 Miscellaneous freight cars and contents	42.3	515,000,000,000
2 Revenue coal cars and contents	16.23	197,000,000,000
3 Locomotive revenue, driver weight only	10.90	132,300,000,000
4 Passenger cars, all classes	16.13	196,000,000,000
Total revenue, freight and passenger	85.56	1,040,300,000 000
5 Railway coal	5.00	60,600,000,000
6 Tenders, all classes	6.50	78,800,000,000
7 Locomotive railway coal	0.39	4,700,000,000
8 Locomotive, non-driving weight	2.55	31,000,000,000
Total non-revenue	14.44	175,100,000 000
Grand total (all classes)	100	1,215,400,000,000

TABLE 2 COAL REQUIREMENTS FOR U. S. RAILROADS IN 1918 REFERRED TO ELECTRICAL UNITS

Total ton-miles, 1918	1,215,400 000,000
Watt hours per ton mile	40
Kw-hr. total movement	48,700,000 000
Coal required at 7 lb. per kw-hr., tons	170 000,000

TABLE 3 COAL SAVING BY ELECTRIFICATION

Total ton-miles, steam	1,215,400,000,000
Reduction by electrification	146 000 000 000
Total ton-miles electric	1,069,400,000,000
Kw-hr. electric at 40 watts	42,776,000,000
Coal on basis $2\frac{1}{2}$ lb. per kw-hr., tons	53,500,000
Equivalent railway coal, 1918, tons	176,000,000
Saving by electrification, tons	122,500,000

From this the author proceeds to an estimate of the cost in pounds of coal to do the same work electrically, taking the conditions existing on certain western railroads. To do this, the ton-mile values of Table 1 are reconstructed into those of Table 2. From this he proceeds to the construction of Table 3 showing the saving of coal by electrification again on the basis of Table 1.

The startling conclusion arrived at is that approximately 122,-500,000 tons of coal, or more than two-thirds the coal now burned in our 63,000 steam engines, would have been saved during the year 1918 had the railways of the United States been completely electrified along lines fully tried out and proved successful today.

The author claims this estimate is probably too conservative as no allowance has been made for the extensive utilization of water power which can be developed to produce power more cheaply than by coal in many favored localities. On the other hand, one should bear in mind his previous statement that many roads of lean tonnage would render no adequate returns upon the large capital investment required by electrification. It would appear, therefore, that essentially the question is more economic than technical.

Of interest in this connection is a passage at the end of the paper referring to the study of the congested tracks of the Baltimore and Ohio Railroad between Grafton and Cumberland. Company coal movement in coal cars and engine tenders constituted over 11 per cent of the total ton-mileage passing over the tracks.

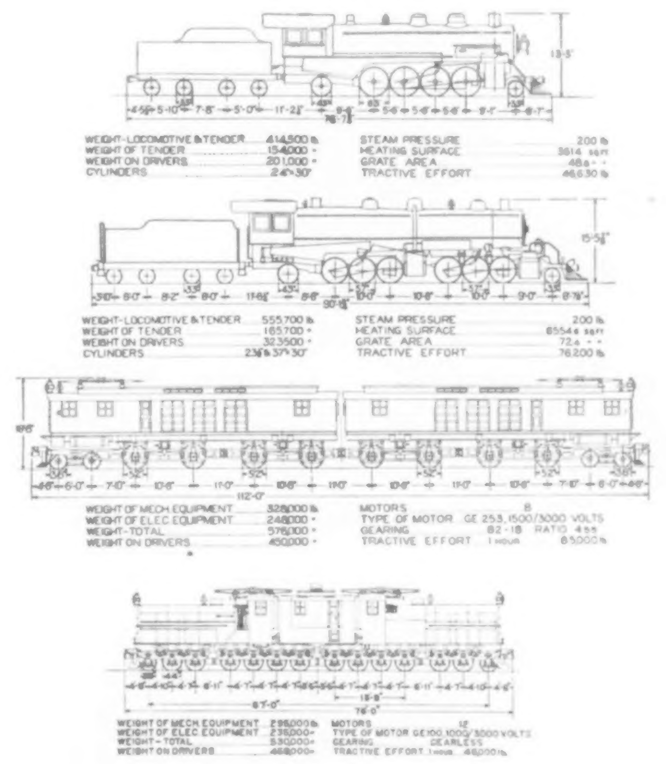


Fig. 14 Diagrammatic Comparison of Steam and Electric Locomotives

In other words, due to the very broken profile of this division, the equivalent of one train in every nine is required to haul the coal burned on the engines.

It is assumed that with the electric-locomotive operation the three tracks now badly congested with present steam-engine tonnage could carry 80 per cent more freight.

Attention is called to Fig. 14 which gives an interesting comparison between steam and electric locomotives. (*Journal of the American Institute of Electrical Engineers*, vol. 39, no. 3, Mar. 1920, pp. 209-218, 11 figs., *d*)

The United States Bureau of Mines announces that it has developed a novel method for giving a danger warning in mines in which compressed air is used throughout the workings. An ill-smelling substance is injected into the compressed-air line and within a few minutes the odor is spread throughout the mine.

STEAM ENGINEERING (See Railroad Engineering)

VENTILATION

Ozone Air Purification

Ozone as the Solution of the Fresh-Air Problem, E. S. Hallett. Description of installations tested out in the public schools of St. Louis, Mo. The Head of the Hygiene Department of the Board of Education of St. Louis came to the Building Department with the complaint from one of the downtown schools that the air was so bad in some rooms that teachers threatened to resign on the advice of their physicians. The writer proposed to the Hygiene Department to test the application of ozone.

The ozone apparatus was set up in the air passage between the air washer and fan, and regulated to produce just sufficient ozone to be barely detected by the odor on entering the building, but not enough to make one conscious of an odor. The result was the actual disappearance of all the stuffy conditions and bad smells complained of. The teachers stated that the conduct of the children as to lessons and behavior was noticeably better. Colds and coughs nearly disappeared. No contagious diseases developed during the six weeks' trial, although the influenza was epidemic at this time. In fact, during the period of an influenza epidemic, the attendance was 30 per cent higher than the general average attendance for this school.

The experiment was then transferred to a colored school having the plenum system with the Zellweger air-washing fan and with complete recirculation of the air. The ozone machine was set up just back of the fan, the ozone acting upon the water of the air washer as well. In this test the pupils and teachers were weighed weekly and a close inspection made by the staff physician of the Hygiene Department. About 75 per cent of the children gained in weight on an average of about one pound, about 5 per cent lost weight, while the rest suffered no change. Several very stout girls weighing about 170 lb. each lost from 5 to 8 lb. weight (total duration of test not stated). No indication of illness or discomfort was noted. No contagious diseases occurred in this school and colds were noticeably less.

The coal consumption was measured, and in comparison with days of equal outside temperature the coal used was almost exactly one half.

Agar plates were exposed in a room filled with pupils and showed an average count of bacteria of 225, which was extremely low, indicating that the ozone had destroyed the active germs of the air.

These and other tests during a year's period indicated that ozone destroys all odors resulting from the respiration, bodies and clothing of the children, and produces a mild exhilaration resembling that of a sea breeze or the air on a morning after a thunderstorm. It appears from limited data to be a preventive of influenza, and it is believed that its introduction in ventilation would probably remove the necessity for open-air schools now common in most cities.

The maximum concentration should be too low to give an ozone odor, and if used up to this concentration is safe for ventilation. Persons not used to ozone in air must be employed for detecting the air, as the sense of smell for ozone quickly declines when exposed to it.

The writer developed a standard which may be used in determining in advance the proper concentration for any given volume of air movement or for a given number of occupants in a room.

This standard was developed after ascertaining that with a given voltage and with a given thickness of dielectric the amount of ozone generated was proportional to the number of brush discharge points of the generator.

The most satisfactory apparatus uses 4000 volts alternating current from a static transformer, all included with the ozone generator unit, which uses a micanite plate dielectric 0.040 in. in thickness and aluminum points spaced approximately ½ in. apart. It was observed that 600 brush points made just enough ozone for 1000 cu. ft. of air from the blast fan.

This test was with rooms filled with 45 to 50 children much below the average in cleanliness. For rooms occupied by fewer people, the brush points or voltage should be reduced. If conditions are to remain constant, some points should be disconnected, but with varying conditions a controller should be installed to regulate the voltage by taking taps out of the primary of the transformers.

Where the air is recirculated in whole or in part, the ozone must be cut down to the point where no ozone odor is noticeable. In fact, the revitalizing of the air of the average school room when recirculating 90 per cent of the air will be effectively done with half the maximum stated above. The writer believes that the delay in the use of ozone in ventilation has been due to trials made with too high concentration and to the absence of any information on a means of control.

Ventilation for its final effect depends on the purity of the air surrounding the building, and if the building, such as a school or hospital, is located in an unhealthy neighborhood, ventilation is apt to do more harm than good. Ozone, by killing the germs in the air, practically creates clean air and is independent in its effect on the location of the building to be ventilated.

The writer proceeds to show a heating system designed in the light of these tests. It has no air washer. (Paper presented at the Annual Meeting of the American Society of Heating and Ventilating Engineers, Jan. 27-29, 1920, under the title, An Advance in Air Conditioning in School Buildings. Compare *Heating and Ventilating Magazine*, vol. 17, no. 2, Feb. 1920, pp. 25-29, 1 fig., *ed*)

The Detection of Invisible Objects by Heat Radiation. In 1918 the United States Army started to devise methods for detecting men and inanimate objects which were at a higher temperature than adjacent things by means of the emitted radiation. A thermopile was placed at the focus of a parabolic mirror. The radiation from the warmer object fell on the mirror and was reflected to the thermopile where it produced an electric current which was observed by means of a galvanometer. It was possible to detect a man 600 ft. away. "A man lying in a depression in the ground at a distance of 400 ft. was detected unfailingly as soon as he showed the upper part of his face above ground." Secret signaling could be carried on by covering and uncovering the face. This apparatus was sent to the A. E. F. in August, 1918.

An aeroplane at an altitude of 3500 ft. could be picked up by such an instrument and its course followed. A wisp of cloud produced confusion by causing as large a deflection as the aeroplane did, but the two possible causes were different in the way in which the galvanometer deflection began.

In an address before the Section on Physics of the American Association for the Advancement of Science, St. Louis, December 1919, Prof. Gordon F. Hull called attention to the rather peculiar fact that in the official manual for the U. S. rifle the value of the ballistic coefficient of the ordinary service rifle bullet of 0.30 in. caliber is given as 0.3894075, "as determined experimentally at the Frankford Arsenal." Commenting on this he said: "The experimental skill which can determine to an accuracy indicated by several places of decimals a quantity as highly capricious as the so-called ballistic coefficient, is of rather questionable value."

CLASSIFICATION OF ARTICLES

Articles appearing in the Survey are classified as *c* comparative; *d* descriptive; *e* experimental; *g* general; *h* historical; *m* mathematical; *p* practical; *s* statistical; *t* theoretical. Articles of especial merit are rated *A* by the reviewer. Opinions expressed are those of the reviewer, not of the Society. The Editor will be pleased to receive inquiries for further information in connection with articles reported in the Survey.

ENGINEERING RESEARCH

A Department Conducted by the Research Committee of the A. S. M. E.

Coöperative Research

AT PRESENT seven associations of manufacturers are supporting research at the Mellon Institute at Pittsburgh. The name of the association, the number of companies and the amount subscribed for the fellowship foundation in each case is given in the following table:

	Number of Companies	Amount
Magnesia Association of America.....	4	$ 6000
Asbestos Paper Manufacturers Assn..	10	3500
Rex Spray Companies...............	9	3500
Laundry Owners National Association	2500	5000
Leather Belting Exchange Corporation	40	5600
Refractories Manufacturers Association	84	10000
Container Club	24	3500

The investigations on magnesia insulation are for the purpose of determining its heat-insulating value. The investigations for the Asbestos Paper Manufacturers are for the purpose of standardizing the specifications for asbestos textiles and asbestos millboard. The Rex Spray fellowship is for the purpose of improving the manufacture of insecticides. The Laundry Owners' fellowship is devoted to the investigation of water, soap, permanency of colors, stains and dyes. The Leather Belting fellowship is for the purpose of determining the comparative power-carrying capacities of leather belts with substitute belts. The fellowship of the Refractories Association is for the purpose of determining standard tests to be used in manufacturing. The Container Club fellowship is in connection with the development of a paper tester and the testing of fiber board with this instrument.

A—Research Results

The purpose of this section of Engineering Research is to give the origin of research information which has been completed, to give a résumé of research results with formulæ or curves where such may be readily given, and to report results of non-extensive researches which in the opinion of the investigators do not warrant a paper.

Apparatus and Instruments A3-20 Gage for Small Pressures. The Wahlen gage was developed by W. G. Wahlen of the Engineering Experiment Station of the University of Illinois. It is sensitive to 0.0001 in. of water. It is composed of a rigid base on leveling screws with two large glass bulbs communicating through a special inverted U-tube. One of the bulbs is controlled by a micrometer caliper. Alcohol of density 0.8195 is used in the bulbs and part of the U-tube. It is colored with aniline dye to give a red color. The upper part of the U-tube is filled with a mixture of turpentine and ligroin of density 0.810. The gages are first balanced at zero with both ends open. The pressure connection is then made and the movable carriage is adjusted to bring the meniscus in the U-tube to its reference point. By using a U-tube with legs of different sizes accurate observations may be made. This gage may be used with pitot tubes for the calibration of instruments or the measuring of low air currents. Address Engineering Experiment Station, University of Illinois, Urbana, Ill. C. R. Richards, Director.

Apparatus and Instruments A4-20 Radiation Effects on Thermocouples. In determining the temperature of the air in hot-air leaders of a warm-air furnace, the Experiment Station of the University of Illinois has found that the radiation from the thermocouples affects the temperature reading shown by them. The temperature of a leader was determined by a thermocouple when the leader was uncovered and when the leader was covered with hair felt. If the temperature of the air going to the leader was found to be the same in each case, the difference shown in the leader would represent the loss due to radiation. This was found to be 26 deg. fahr. when the temperature observed was 195 deg. fahr. Engineering Experiment Station, University of Illinois, Urbana, Ill. Address C. R. Richards, Director.

Buildings A1-20 Vibration. A preliminary report by the Aberthaw Construction Company on the Effects of Vibration in Structures has been issued. This gives a statement of the research from 1133 replies in connection with this investigation. The report mentions the natural frequencies of vibrations, the method of recording vibrations, method and type of construction, the reduction of efficiency and production caused by vibration, experiments in various forms of mills, methods of absorbing vibration, methods of tracing vibration, types of building used and methods of design. Address Aberthaw Construction Company, 27 School St., Boston, Mass.

Fuels, Gas, Tar and Coke A2-20 The Comparative Value of Fuels, by M. K. Thornton, Jr., issued by the Texas Engineering Station, College Station, Tex. Address J. C. Nagle, Director.

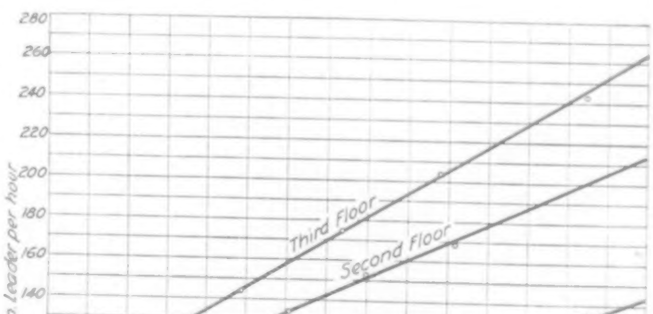


Fig. 1 Curves Showing Effect of Register Temperature on Leader Capacity

Fuels, Gas, Tar and Coke A3-20 Wood. The fuel value of wood is given by the Forest Products Laboratory. Two pounds of dry wood of any non-resinous species has the heating value of 1 lb. of good coal. Resin gives about twice as much heat as the wood. As the average amount of resin is 15 per cent. this increases the heating value 30 per cent. One cord of hickory, oak, beech, birch, hard maple, ash, elm, locust, long-leaf pine or cherry is equal to one ton of coal; and 1½ cords of short-leaf pine, Western hemlock, red gum, Douglas fir, sycamore and soft maple are equal to one ton of coal. Two cords of cedar, redwood, poplar, catalpa, cypress, basswood, spruce or white pine are equal to one ton of coal. Forest Products Laboratory, Madison, Wis. Address Director.

Heating A5-20 Warm-Air Furnaces. Bulletin No. 112 of the Engineering Experiment Station of the University of Illinois, on the Progress of the Warm-Air Furnace Research, by A. C. Willard, has been issued. The report describes the method of measuring temperature and allowing for the radiation effect, the method of measuring air at low velocities with anemometers and pitot tubes using the Wahlen gage accurate to 0.0001 in. of alcohol. Researches indicate that a square inch of leader pipe on the first floor has a far less heating and carrying value than that for second- or third-floor leader pipe. The tests indicate that the capacity of a warm-air furnace system is greatly reduced by dampering leaders to the upper floors. The temperature at register faces should be 175 deg. fahr. The amount of heat delivered per square inch of leader area is given by the three curves in Fig. 1. The efficiency of the furnace as installed is shown by the curve in Fig. 2, below which is shown the arrangement of the installation. Engineering Experiment Station, University of Illinois, Urbana, Ill. Address Director C. R. Richards.

Hydraulics A1-20 Sewage Sprinkler Nozzles and Coefficient for Discharge. The discharge from sewage sprinkler nozzles can be represented by the equation $Q = CA\sqrt{(2gh)}$ after the head on the sprinkler is greater than 1½ ft. At lower heads the coefficient decreases. The exponent of the head is practically 0.5. Seven different nozzles were tested with the following coefficients:

Chase square nozzles	0.648
Taylor round nozzles	0.756
Taylor square nozles	0.696
Worcester round nozzles, 13/16 in.	0.660
Worcester round nozzles, 11/16 in.	0.675
Merritt square nozzle	0.598
Priestman-Beddoes round nozzle	0.569

Internal-Combustion Motors A1-20 Spark Plugs. The Fifth Annual Report of the National Advisory Committee for Aeronautics will contain a report on the properties and preparation of ceramic insulators for spark plugs. Report No. 53, in four parts, gives the results of research and development work conducted by the Bureau of Standards at the instance of the National Advisory Committee for Aeronautics. A discussion is given of the methods for measuring the resistance of insulators at high temperatures and the method finally adopted for this work is described. Results of tests of a large number of insulating materials at high temperatures are tabulated and their significance discussed. The preparation and composition of ceramic insulators is outlined and compositions are given of new porcelains having superior properties. Results of an experimental investigation into the corrosion effects and permanency of various cements for spark-plug electrodes are discussed. The four parts of this Report are entitled as follows:

Part I Methods of Measuring Resistance of Insulators at High Temperatures, by F. B. Silsbee and R. K. Honaman.

Part II Electrical Resistance of Various Insulating Materials at High Temperatures, by R. K. Honaman and E. L. Fonseca.

Part III Preparation and Composition of Ceramic Bodies for Spark Plug Insulators, by A. V. Bleininger

Part IV Cements for Spark-Plug Electrodes, by H. F. Staley. Address National Advisory Committee for Aeronautics, Washington, D. C.

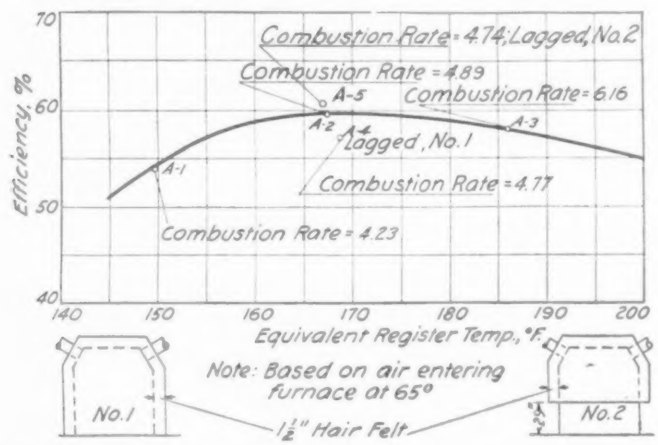


FIG. 2 EFFICIENCY CURVE FOR A FURNACE OPERATING AT VARIOUS REGISTER TEMPERATURES AND RATES OF COMBUSTION

Light A1-20 Reflectometer. The Bureau of Standards has developed a new reflectometer after extensive experiments. The instrument is to be used to determine the amount of reflection from walls to rooms. It consists of a small metal sphere from which a segment has been removed leaving about nine-tenths of its original surface. It is painted inside with a diffusing white paint and a beam of light is projected through a small hole in the wall to the surface which is to be tested. The test surface may be compared with the standard surface or with a flat surface painted with the same paint as the sphere. Bureau of Standards, Washington, D. C. Address S. W. Stratton, Director.

Lubricants A1-20 Solid Lubricants. The Department of Scientific and Industrial Research of Great Britain has recently prepared a memorandum on solid lubricants. This can be obtained for sixpence from H. M. Stationery Office at No. 20 Abingdon St., Westminster S. W. 1., London, England. The subject is dealt with under the following headings:

1. Characteristics of Solid Lubricants
2. Action of Solid Lubricants
3. Analyses of Lubricating Graphites
4. The Grading of Graphite
5. Hot Bearings
6. Methods of Applying Solid Lubricants
7. Drawbacks to the Use of Colloidal Solid Lubricants
8. Observations on Results Obtained by the Use of Solid Lubricants.

Mining A1-20 Concentrating Minnesota Wash Ores. A new machine for concentrating Minnesota wash ores. Bulletin No. 6 of the Engineering Experiment Station of the Minnesota School of Mines. Address W. R. Appleby, Director, Minneapolis, Minn.

Mining General A2-20 Panel Systems of Coal Mining, by C. M. Young. A graphical study of the percentage of extraction by the panel system of coal mining. The paper shows that the greatest extraction with room 300 ft. long and 30 ft. wide on 50-ft. centers is only 57.05 per cent and with 40-ft. rooms 68.48 per cent. The Bulletin shows the reasons for low extraction, the advantages of high extraction and the method of investigating the percentage extraction. Engineering Experiment Station, University of Illinois, Urbana, Ill. Address Director.

Properties of Engineering Materials A4-20 Boiler Plate at Elevated Temperatures. A series of tests on cold-rolled boiler plate at temperatures has just been made. The curves from the tensile tests show the same variations as those obtained with temperature increases on hot-rolled plates with the exception of the range from 475 deg. fahr. to 675 deg. fahr., where the proportional limit suddenly increases and the reduction of area shows a distinct decrease. The tensile strength also registers a sharp change. Bureau of Standards, Washington, D. C. Address S. W. Stratton, Director.

Properties of Engineering Materials A5-20 Granite and Indiana Limestone. Investigations on the properties of commercial granites of the United States has been commenced and tests have been completed on twelve varieties used in the eastern part of the country. Seventy-two samples of Indiana limestone have been studied and the results are available for those interested in the subject. The summary gives the tensile strength, transverse strength, absorption, porosity and weight per cu. ft. Bureau of Standards, Washington, D. C. Address S. W. Stratton, Director.

Properties of Engineering Materials A6-20 Over-Sanded Concrete. In order to make certain concrete mixtures more workable it has been proposed to introduce additional sand. The Bureau of Standards has investigated a 1:2:4 limestone concrete and a 1:3:3 mixture of the same substances. After 28 days the latter mixture gave 988 lb. per sq. in. while the former gave 768 lb. per sq. in. The latter sample took 487 lb. of cement per cu. yd. while the former took 508 lb. per cu. yd. This shows the advantage of over-sanding. Further tests are under way. Bureau of Standards, Washington, D. C. Address S. W. Stratton, Director.

Wood Products A6-20 Gluing. When large glue joints are to be made, high strength of the whole joint is obtained by heating the wood for 10 or 15 min. to a temperature of 120 deg. fahr. before gluing. Forest Products Laboratory, U. S. Forest Service, Madison, Wis. Address Director.

B—RESEARCH IN PROGRESS

The purpose of this section of Engineering Research is to bring together those who are working on the same problems for coöperation or conference, to prevent unnecessary duplication of work and to inform the profession of the investigators who are engaged upon research problems. The addresses of these investigators are given for the purpose of correspondence.

Aircraft B3-20 Model Tests. The theory of model tests of flying boats. Address Curtiss Research Laboratory, Curtiss Engineering Corporation, Garden City, L. I.

Aircraft B4-20 Static Pressure Gradients. The theory of static pressure gradients in wind tunnels; method of eliminating pressure gradients and short method of correcting for pressure gradients. Address Curtiss Research Laboratory, Curtiss Engineering Corporation, Garden City, L. I.

Aircraft B5-20 Pressure Gages. Absolute pressure gage for wind-tunnel work. Address Curtiss Research Laboratory, Curtiss Engineering Corporation, Garden City, L. I.

Aircraft B6-02 Cable Air Resistance. Tests on resistance of multiple airplane cables behind each other at varying amounts of separation. Address Curtiss Engineering Corporation, Garden City, L. I.

Apparatus and Instruments B3-20 Absolute Pressure Gage for Wind-Tunnel Work has been designed and constructed at Curtiss Research Laboratory. Address Curtiss Engineering Corporation, Garden City, L. I.

Chemistry, Inorganic B1-20 Fixation of Atmospheric Nitrogen. An investigation of a number of factors for increasing the efficiency of the arc process in the fixation of atmospheric nitrogen, by Prof. E. A. Loew and F. K. Kirsten, Engineering Experiment Station, University of Washington, Seattle, Wash. Address C. E. Magnusson, Acting Director.

Electrical Communication B1-20 Multiplex Radiotelephony. An investigation for sending five radio telephone messages from same antenna and reception of these through single antenna. F. M. Ryan, J. R. Tolmie, Roy Bach, A. Kalin, graduate students in

Electrical Engineering. Engineering Experiment Station, University of Washington, Seattle, Wash. Address C. E. Magnusson, Acting Director.

Electrical Instruments B1-20 Order and Amplitude of Harmonics in Voltage Waves. A method for determining the order and amplitude of harmonics in voltage waves by indicating meters. A wave analyzer is being constructed to apply this method. Prof. L. F. Curtiss, Engineering Experiment Station, University of Washington, Seattle, Wash.

Electrical Instruments B2-20 Oscillograph. A convenient timing device for use with the oscillograph. A convenient method for producing time waves of any desired frequency. J. R. Tolmie, Engineering Experiment Station, University of Washington, Seattle, Wash. Address C. E. Magnusson, Acting Director.

Electric Power B1-20 Trunk Transmission Lines. An investigation on the need for trunk transmission lines on the Pacific Coast by C. E. Magnusson, Engineering Experiment Station, University of Washington, Seattle, Wash. Address C. E. Magnusson, Acting Director.

Glass and Ceramics B1-20 Enamels. The Bureau of Standards is investigating the formation of fish-scaling in enamels on sheet steel and also the subject of the relation of the composition of the enamel to solubility in acids. They have made over 4000 sample enamel plates comprising 21 different enamels in the production of fish-scaling and 33 enamel compositions have been tested for the solubility in acids. One of the most important factors in producing fish-scaling is too severe heat treatment in firing the enamel. The composition of the enamel and the physical and chemical characteristics of underlying metal together with the method of melting the mixture and the shape and weight of the mixture are important factors. The work on the acid-resisting properties indicates that oxides which are chemically similar in nature do not have similar effects when incorporated in enamel compositions. Thus calcium chloride is not so good as barium oxide. Bureau of Standards, Washington, D. C. Address S. W. Stratton, Director.

Heat B4-20 Evaporation from Liquid Surfaces. Address Curtiss Engineering Corporation, Garden City, L. I.

Internal-Combustion Motors B3-20 Available Fuels. An investigation of available fuels for internal-combustion engines in the future using suggested manifold and heater for the application of high-boiling-point fuels. J. G. Vincent, Packard Motor Car Company, Detroit, Mich.

Properties of Engineering Materials B10-20 Cables. Tramway Cable Loaded at One Point, by S. Herbert Anderson. An investigation to obtain equations which completely describe the conformation taken by a flexible chain or cable anchored with one end at a higher level than the other and loaded at any one point such as a tramway cable or logging skyline. Equations have been obtained for easy computation of tension at any point, maximum tension for given loading and position of load for maximum tension. Equation contains three constants or parameters, one of which is expressed in terms of the other two. Constants can be determined from weight of cable per unit of length, amount of load, and heights of end points above load. University of Washington, Seattle, Wash. Address C. E. Magnusson, Director.

Textile Manufacture and Clothing B1-20 Methods of Determining the properties of cotton fibers with respect to their manufacturing properties. These methods are to be used in connection with determining the effect of the present manufacturing properties in the interest of higher-speed textile machinery and more economical use of cotton fibers. Textile Research Company, 34 Batterymarch St., Boston, Mass. Address E. D. Whalen, Manager.

Transmission B3-20 Wood Pulleys. An investigation of pulleys prepared from spruce. Pulleys built up in the same manner as hardwood pulleys. Density of the spruce fibers increased by compression at right angles to grain to one-half of original volume. Tests being made are those for frictional driving power and investigations of mechanical strength, and are in charge of Prof. G. S. Wilson, Engineering Experiment Station, University of Washington, Seattle, Wash. Address C. E. Magnusson, Acting Director.

C—RESEARCH PROBLEMS

The purpose of this section of Engineering Research is to bring together persons who desire coöperation in research work or to bring together those who have problems and no equipment with those who are equipped to carry on research. It is hoped that those desiring coöperation or aid will state problems for publication in this section.

Automotive Vehicles and Equipment C1-20 Resistance of Automobile Bodies. Tests on resistance of automobile bodies at various speeds. Address Curtiss Engineering Corporation, Garden City, L. I.

E—RESEARCH PERSONAL NOTES

The purpose of this section of Engineering Research is to give notes of a personal nature regarding the personnel of various laboratories, methods of procedure for commercial work or notes regarding the conduct of various laboratories.

Heating E1-20 The work of the Engineering Experiment Station at Pennsylvania State College in connection with heating and ventilation is being conducted along the lines of obtaining the coefficient of heat transmission by means of the "Hot Box." This method gives the effects of conduction as well as the surface effects. The work is under the direction of Prof. A. J. Wood. Address Dean R. L. Sackett, Pennsylvania State College, State College, Pa.

Heating E2-20 Warm-Air Furnace Research, by A. C. Willard. Among the various problems to be carried on in the researches connected with warm-air furnace heating may be mentioned the following:

Transmission, efficiency and capacity with various register temperatures with draft not to exceed 0.2 in. of water. The length of firing period is also to be investigated. The heat- and air-carrying capacities and heat losses in various kinds and sizes of leaders and stacks are to be investigated. Losses in boots and registers are to be determined as well as the length and pitch of leaders. Comparison of relative efficiency and capacity of various furnaces of same grate area but of different amounts and arrangements of heating surface. Comparison between hard- and soft-coal furnaces. A study of cold air and recirculation. A standard method of rating furnaces. The effects of modifying the design and installation. Address Director C. R. Richards, Engineering Experiment Station, Urbana, Ill.

Iowa State College, Engineering Experiment Station E1-20 The Engineering Experiment Station was organized in 1904 and receives an appropriation of \$35,000 per annum. The complete equipment of the Engineering School is available for the Experiment Station. The application of mechanical engineering to agricultural machinery, including tractors, receives considerable attention. Iowa State College, Agriculture and Mechanical Arts, Ames, Iowa. Address Anson Marston, Director.

Texas Engineering Experiment Station E1-20 The Texas Engineering Experiment Station, College Station, Texas, has issued twenty-two Bulletins, fourteen of them dealing with highway engineering, one with chemistry, one with cotton cultivation, one with purchasing, one with geology, three with homes and one with fuels. Address J. C. Nagle, Director, Texas Engineering Experiment Station, Agricultural and Mechanical College of Texas, College Station, Texas.

F—BIBLIOGRAPHIES

The purpose of this section of Engineering Research is to inform the profession of bibliographies which have been prepared. In general this work is done at the expense of the Society. Extensive bibliographies require the approval of the Research Committee. All bibliographies are loaned for a period of one month only. Additional copies are available, however, for periods of two weeks to members of the A.S.M.E. or to others recommended by members of the A.S.M.E. These bibliographies are on file in the offices of the Society.

Chemistry, General, F1-20 Chemical Warfare. A bibliography of 12 pages prepared by Dr. Clarence J. West of the Arthur D. Little Co., Inc. Address Arthur D. Little, Inc., Cambridge, Mass.

Chemistry, Organic F2-20 Alcohol. The Production of Alcohol from Sulphite Waste Liquors. A bibliography of 6 pages prepared by Dr. Clarence J. West of the firm of Arthur D. Little, Inc. Address Arthur D. Little, Inc., Cambridge, Mass.

Electrochemistry F1-20 Electric Furnaces, Design and Construction. Search 2880. A bibliography of 5½ pages. Address A. S. M. E., 29 West 39th St., New York.

Fuels, Gas, Coal and Coke F1-20 Colloidal Fuels and Low-Temperature Distillation of Coal. A bibliography of 1½ pages. Search 2878. Address A. S. M. E., 29 West 39th St., New York.

Heat F1-20 Utilization of Waste Heat for Generating Steam. A bibliography of 3 pages. Search 2741. Address A. S. M. E., 29 West 39th St., New York.

Hydraulics F2-20 Sprinkler Nozzles, by F. W. Greve and W. E. Stanley. A bibliography of 6 references on sewage sprinkler nozzles. Address A. S. M. E., 29 West 39th St., New York.

Metallurgy and Metallography F2-20 Electric Furnaces. See Electrochemistry F1-20.

Research F1-20 Industrial Research. A bibliography of 8 pages on a reading list on Industrial Research, prepared by Dr. Clarence J. West and Edward D. Greenman of Arthur D. Little, Inc. Address Arthur D. Little, Inc., Cambridge, Mass.

Work of the Boiler Code Committee

The Boiler Code Committee meets monthly for the purpose of considering communications relative to the Boiler Code. Any one desiring information as to the application of the Code is requested to communicate with the Secretary of the Committee, Mr. C. W. Obert, 29 West 39th St., New York, N. Y.

The procedure of the Committee in handling the cases is as follows: All inquiries must be in written form before they are accepted for consideration. Copies are sent by the Secretary of the Committee to all of the members of the Committee. The interpretation, in the form of a reply, is then prepared by the Committee and passed upon at a regular meeting of the Committee. This interpretation is later submitted to the Council of the Society for approval, after which it is issued to the inquirer and simultaneously published in MECHANICAL ENGINEERING, in order that any one interested may readily secure the latest information concerning the interpretation.

Below are given the interpretations of the Committee in Cases Nos. 273-282, inclusive, as formulated at the meeting of February 26, 1920, and approved by the Council. In accordance with the Committee's previous practice, the names of inquiries have been omitted.

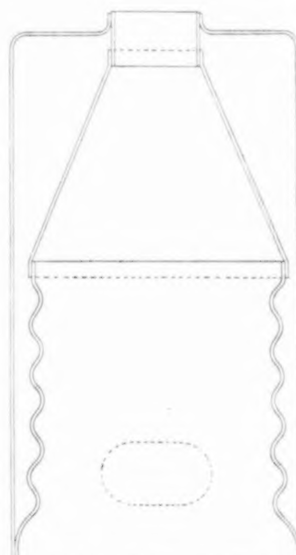


FIG. 3 VERTICAL SINGLE-FLUE BOILER WITH CORRUGATED FIRE BOX

CASE No. 273

Inquiry: Does Par. 296 of the Boiler Code require that the tee or lever-handled cock be placed immediately under the steam gage where a long connecting pipe is used and the locked-open valve is permitted close to the boiler?

Reply: It is the intent of the requirement in Par. 296 that the tee or lever-handled valve shall be located near to the steam gage so that it will be readily evident to any one observing the gage, even though the locked-open valve is used at or near the boiler.

CASE No. 274

Inquiry: Is it permissible to use upon an h.r.t. boiler with the third return type of setting, an extended nozzle formed of a short length of pipe screwed into flanged fittings at the boiler connection and the outer end, in order that it may reach well above the boiler brickwork?

Reply: The construction proposed will not meet the Code requirements, where the pipe is over 3 in. pipe size and the working pressure exceeds 100 lb. per sq. in. A double-flanged nozzle riveted to the boiler shell should be provided, one form of which is illustrated in Case No. 232, or a standard pressed-steel nozzle may be used in lieu of the one illustrated by Case No. 232. If such standard nozzle is used, it should be protected by insulation.

CASE No. 275

Inquiry: Is autogenous welding permissible for the longitudinal joint of the fire box of a form of vertical boiler as shown in Fig. 3, where the furnace section is, after welding, heated and corrugated by rolls? The corrugations are rolled to a depth of $1\frac{1}{2}$ in. on 8 in. centers, and the weld shows no fracture or distress after either corrugating or flanging.

(In the hands of the Committee)

CASE No. 276

Inquiry: In the design of a cast-steel water box to be set in the side walls of furnaces and to be subjected to full boiler pressure, is it necessary to apply to the sections containing flat surfaces, the formula in Par. 199 of the Boiler Code, using C = 120, or is it necessary to use this formula with the value of C = 156?

Reply: It is the opinion of the Committee that the construction of pressure parts of the type referred to is provided for by Pars. 9 and 247. If the Secretary of the Boiler Code Committee can be notified when the specimen is ready for test, steps will be taken to have a representative of the Committee present.

CASE No. 277

Inquiry: *a* An interpretation is requested of the application of Par. 212*a* of the Boiler Code with reference to any curved stayed surface subject to internal pressure. Does this refer to both the outer and furnace sheets of vertical tubular boilers?

b If under the requirements of Par. 239 of the Boiler Code relative to furnaces under 36 in. in diameter, the design of the furnace does not permit of operation without staying, is there any rule in the Code for the staying in this case, or must the furnace sheets be stayed as flat surfaces, using Table 4 for the pitch?

c Is it the intent of Par. 212*c* of the Boiler Code that the increased pitch allowed, may be used for the same working pressure and thickness of plate as indicated in Table 4? It is the understanding that Table 4 is based on the formula given in Par. 199.

Reply: *a* The term "curved stayed surface subjected to internal pressure" in Par. 212*a* of the Code is intended to refer to any surface in a boiler structure that is subjected to pressure on the concave side. It therefore refers only to that part of the outer shell of a vertical tubular boiler which is stayed.

b Where a furnace under 36 in. in diameter requires staying, it should be stayed as a flat surface as provided for in Table 4, except that the pitch may be increased as indicated in Par. 212*c*.

c It is the intent of Par. 212*c* that the increased pitch there permitted, may be used for the same steam pressure and thickness of plate as specified in Table 4.

CASE No. 278

(In the hands of the Committee)

CASE No. 279

(In the hands of the Committee)

CASE No. 280

Inquiry: *a* Is it permissible under the requirements of the

Boiler Code to use a blow-off valve of the type used on locomotive boilers, operated by a lever lift, for stationary boilers?

b Is it considered safe to use superheated steam of 125 lb. pressure and 125 deg. of superheat, or total nominal temperature of 478 deg., with a piping system having extra-heavy cast-iron fittings and medium-weight cast-iron valves?

Reply: *a* It is the opinion of the Committee that the blow-off valves required by Par. 311 for stationary boilers, may be of the lever-lift type, provided they are of extra-heavy construction, and so designed that they may be operated without shock to the boiler.

b Attention is called to Par. 12 of the Code which states that cast iron shall not be used for nozzles or flanges attached directly to the boiler for any pressure or temperature, nor for boiler and superheater mountings such as connecting pipes, fittings, valves and their bonnets, for steam temperatures of over 450 deg. fahr. While the Code only covers the parts therein specifically mentioned, this paragraph clearly indicates the judgment of the Committee as to the safety of the construction in question.

Case No. 281

Inquiry: Is it the intent of Par. 306 of the Boiler Code that every superheater shall be so fitted with a drain that it can actually be completely drained? Many superheaters are fitted with drains which are, however, unable on account of their positions, to completely drain the apparatus.

Reply: It is the opinion of the Committee that every superheater should be so fitted with a drain as to substantially free the superheater from water when the drain is opened.

Case No. 282

Inquiry: Is it the intent of the Boiler Code Committee that the diameter at the base of the threads on the threaded ends of through rods or braces for h.r.t. boilers, shall be equal to or greater than the nominal diameter of the rod? Fig. 14 and Pars. 208 and 211 would seem to infer that it should be at least equal, but isn't it preferable to make it greater, so that the point of greatest weakness in the rod may not be in the threaded portion where permanent set due to strain would tend toward fracture?

Reply: It is the opinion of the Committee that it will be desirable that the threaded ends of through rods or braces for h.r.t. boilers, shall be sufficiently upset so that the minimum diameter at the base of the threads is in excess of the nominal diameter of the rod.

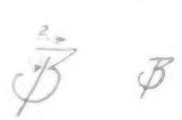
CORRESPONDENCE

CONTRIBUTIONS to the Correspondence Departments of Mechanical Engineering by members of The American Society of Mechanical Engineers are solicited by the Publication Committee. Contributions particularly welcomed are suggestions on Society Affairs, discussions of papers published in this journal, or brief articles of current interest to mechanical engineers.

Proposed Symbol for B. T. U.

To the Editor:

For some fifteen years I have used the following symbol as a substitute for the three letters of B.T.U.:



You will note that the three letters are combined and are speedily produced in two strokes without the use of periods. Having found it very convenient, I am submitting it to you for possible publication in the hope that others interested might find it equally helpful.

R. L. Weber.

Kansas City, Mo.

Calculation of Stresses in a Rectangular Plate

To the Editor:

There are several formulæ in the handbooks for the solving of stresses in rectangular plates, but so far as the writer knows, each one of them is either empirical in its nature or has been mathematically derived from an assumption which is admittedly not true, but which, it is hoped, approximates the truth more or less closely. The writer, therefore, starting with such an assumption, presents a method for calculating the stresses in a rectangular plate supported at its four edges and loaded perpendicularly to its surface, and hopes that some light may be thrown upon the subject which will definitely determine whether or not the assumption and the method based upon it are correct.

It is a well-established fact of mechanics that in an ordinary beam the stress at any point, due to the combination of several loads upon the beam, is equal to the algebraic sum of the stresses caused at that point by each of the several loads taken independently. The writer assumes that this same method can be used to solve rectangular plates by first finding for a given point the stress, considering the plate as a simple beam supported on only two of its opposite edges, and then finding the stress for the same point, considering the plate as a simple beam supported on its other two opposite edges, and finally by combining these two stresses to obtain the magnitude and direction of the stress in the rectangular plate when supported at all four edges. As these two stresses are at right angles to each other they must be combined vectorially, which makes the resultant stress equal to the square root of the sum of the squares of the two simple beam stresses.

In solving these two simple beams we cannot take the same loading for each simple beam as we have on the rectangular plate itself, because then upon combining the two simple beams, the combined loading would be greater than the loading on the rectangular plate itself. What we must do is to take such loading on each of the two simple beams that the summation of their loading equals the loading on the rectangular plate.

In order to take the simplest possible case, we will consider a square rectangular plate of length L, uniform thickness d, with a uniformly distributed load upon its surface of w lb. per square unit of surface, and with all four of its edges supported freely.

Obviously, as the plate is perfectly symmetrical, we should make the loading on each simple beam half the value of the loading on the rectangular plate, i. e., $\frac{1}{2}w$ lb. per square unit of surface. Following this through, we find that the stress at the center of the square plate is $\frac{3\sqrt{2}wL^2}{8d^2}$, and its direction is along the diagonal of the square. The stress at the middle point of each edge is $\frac{3wL^2}{8d^2}$, with a direction along the edge itself. The stress at each of the four corners is zero. The stress for other points in the plate could be found similarly.

An additional assumption is needed for the solving of rectangular plates that are not square, but the writer does not think

it worth while to take up in detail this more complicated case until the assumption for the solving of square plates has been proved. He therefore gives only the result, as follows: Taking the same conditions for the rectangular plate as for the square plate, except that the rectangle has sides of length a and b, the stress at the center becomes $\dfrac{3wa^2b^2\sqrt{a^2+b^2}}{4t^2(a^2+b^2)}$

The writer concludes with the statement that if this method is correct it can be used as the basis of the calculation of such problems as determining the thickness of cylinder heads, steamchest covers, and other problems involving flat plates.

H. W. SIBERT.

Galesburg, Ill.

Strength of Thick Hollow Cylinders

TO THE EDITOR:

In the discussion on my paper on Valves and Fittings for High Hydraulic Pressures, presented at the Annual Meeting of the A. S. M. E. in 1918[1], the point was made that the formula used for the strength of hydraulic pipes and cylinders was difficult to apply, especially when contrasted with the greater simplicity of Barlow's formula. The method which I used was based on the results of experiments by Cook and Roberts, published in London *Engineering*, December 15, 1911, which, after considerable study, I was convinced offered the best basis for design.

[1] Trans. Am.Soc.M.E., vol. 40, page 977.

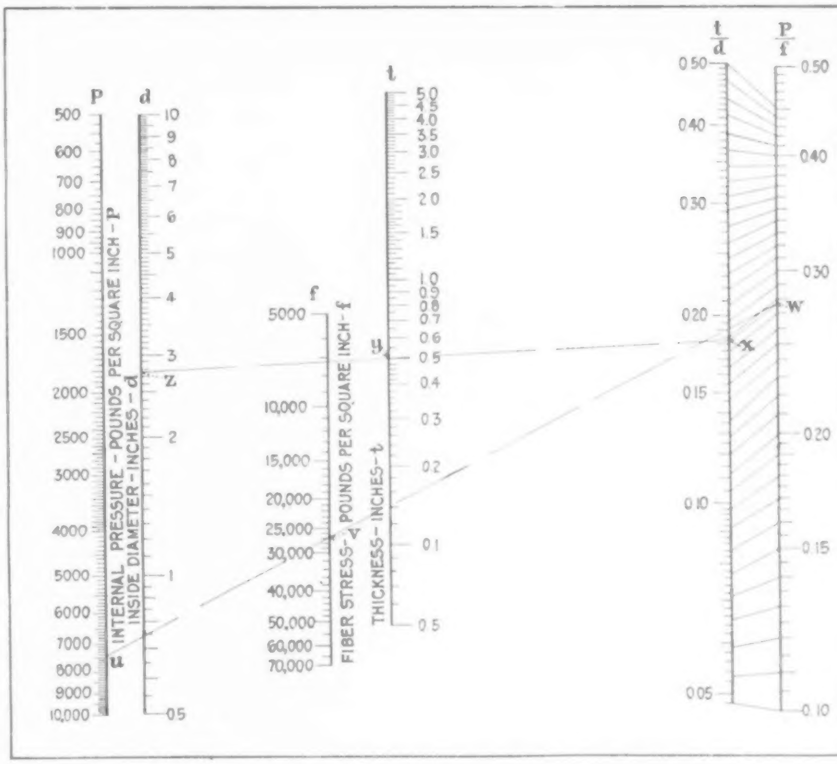


FIG. 1 STRENGTH OF THICK HOLLOW CYLINDERS

FORMULA: $t = -r \pm \sqrt{Pr^2/(0.6f - p) + r^2}$, in which $r = 0.5\,d$.

EXAMPLE: Given $P = 7500$ lb. per sq. in.; $f = 27{,}000$ lb. per sq. in.; $d = 2\frac{3}{4}$ in. *Solution:* Draw line *uvw* from 7500 on P-scale through 27,000 on f-scale, cutting P/f-scale at 0.278; next draw *wx* to t/d-scale, cutting it at 0.183; then draw *xyz* to $2\frac{3}{4}$ on d-scale, cutting t-scale at 0.50 +, which gives required thickness.

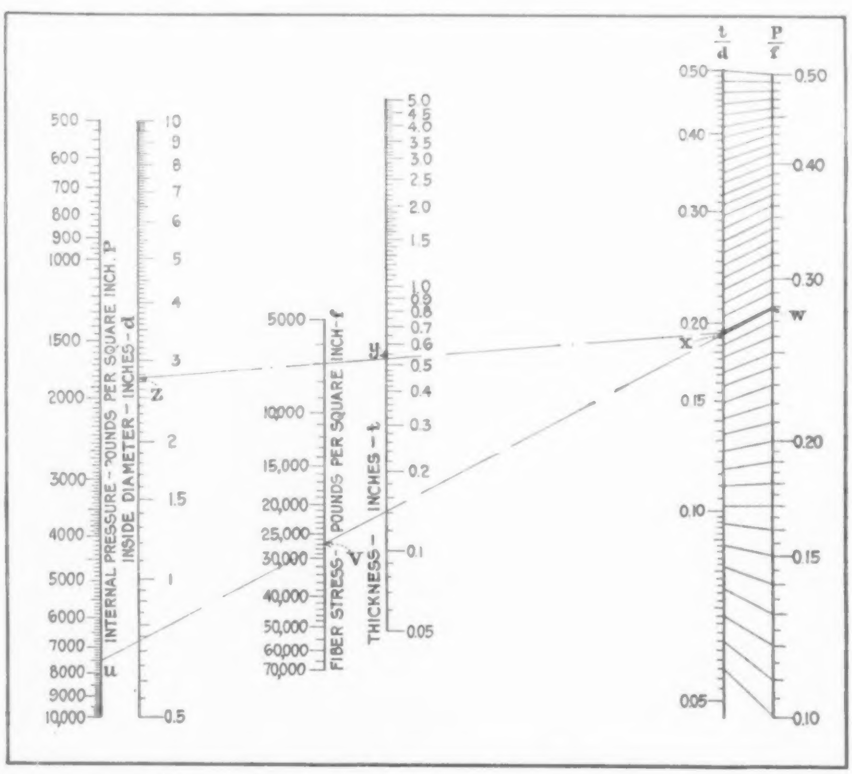


FIG. 2 STRENGTH OF THICK HOLLOW CYLINDERS

BARLOW'S FORMULA: $P/f = t/R$, or $P/f = 2t/(d + 2t)$, in which P = internal pressure; f = fiber stress; t = thickness; r = outside radius; d = inside diameter.

EXAMPLE: Given $P = 7500$ lb. per sq. in.; $f = 27{,}000$ lb. per sq. in.; $d = 2\frac{3}{4}$ in. *Solution:* Draw line *uvw* from 7500 on P-scale through 27,000 on f-scale, cutting P/f-scale at 0.279; next draw *wx* to t/d-scale, cutting it at 0.193; then draw *xyz* to $2\frac{3}{4}$ on d-scale, cutting t-scale at 0.53, which gives required thickness.

Recently, having occasion to calculate some piping, I found that I could make a chart, using the principles of the formula given in my paper, by which the strength of almost any cylinder could be obtained without calculation. I am enclosing a print of this chart, and also one for the application of Barlow's formula which I find many designers use. It will be noted that these two charts are the same except for the relation lines between the P/f and t/d scales at the right side of the chart. The charts are self-explanatory and will be found time savers and sufficiently accurate for any ordinary case.

WM. W. GAYLORD.

Torrington, Conn.

A national association of present and former officers of the Corps of Engineers and civil engineers who have served in any branch of the army—Engineers, Ordnance, or Signal Corps; Infantry, Cavalry or Artillery—is being organized in Washington by a committee appointed by the Chief of Engineers. The objects of this society are to promote the science of military engineering, and to foster the cooperation of all arms and branches of the service, and of civilian engineers in that science. Provisions have been made for an annual meeting, the date of which is to be fixed with reference to that of the American Society of Civil Engineers, in order that members may attend both meetings. The annual dues will not exceed \$5 per year. Further information regarding the society may be secured from Col. G. A. Youngberg, Office of the Chief of Engineers, U. S. Army, Washington, D. C.

Standard Sizes for Shafting

Committee of the A.S.M.E. Recommends 14 Sizes of Transmission Shafting and Large Reduction in Number of Sizes of Machinery Shafting

THE desirability of reducing the number of sizes of shafting and in consequence the number of parts of power-transmission equipment that must be carried in stock has long been recognized. It remained for the conditions of the war, however, to bring about definite action in this regard, from the standpoint of the conservation of materials. The activities of the Committee of The American Society of Mechanical Engineers on War Industries Readjustment brought to light the fact that an immense amount of steel is continuously tied up in manufacturers' and dealers' stocks of shafting and that a corresponding amount of cast iron is also held in stock in the form of hangers, bearings, couplings, collars, bushings, pulleys, etc. At the suggestion of the chairman of the Committee on War Industries Readjustment, therefore, a committee was formed to investigate the subject of the standardization of shafting sizes. The personnel of this committee is as follows:

Cloyd M. Chapman, *Chairman*	Geo. N. Van Derhoef
Hunter Morrison	Louis W. Williams
Russell E. Nelles	

This Committee was confronted with two distinct but closely related problems, viz., the standardization of the diameters of shafting used for the transmission of power, such as lineshafts, countershafts, etc., and the standardization of the diameters of shafting used by machinery manufacturers in making up their product. The first of these problems seemed to be the simpler of the two. While a large number of sizes of transmission shafting are now listed and stocked, it was believed that a comparatively few of these are in extensive general use. Accordingly, a letter was sent to 36 of the largest manufacturers and dealers in transmission shafting asking for statistics on the consumption of each size of shafting handled by them. Some 20 of the largest concerns in the industry furnished complete statements of their sales over periods of time chosen by themselves. These data were reduced by the committee to a uniform basis of percentages. The amount of each size sold was expressed as a percentage of the total sales, both on a weight basis and on a lineal-foot basis. From these data, plotted in the form of a diagram, it was very evident which of the sizes were popular and generally used and which were more rarely called for. A tentative list of 12 sizes was prepared from this diagram and sent to forty-six other dealers in transmission shafting and shafting supplies from whom twenty replies were received.

In the letters to these firms, the committee expressed the opinion that the custom of using shafting $\frac{1}{16}$ in. under the unit sizes is so firmly and so nearly universally established in this country, that it would be unwise to attempt to adopt sizes in even inches and fractions as standard. It was pointed out, also, that certain sizes stand out preëminently as "popular sizes" and that others are sold in relatively small quantities. It seemed very feasible to select a series of standard sizes which would meet the popular demand and give a sufficient selection of sizes for general purposes and at the same time reduce the number of sizes now listed by the trade from some 50 or 60 down to 12 or 15.

The response to these letters was hearty and practically unanimous in opinion. The transmission-shafting users and dealers, almost to the last one, approved the plan of standardization and the sizes suggested were very generally approved except that the diameters $1\frac{11}{16}$ in. and $2\frac{7}{16}$ in. were in many cases requested to be included. After due consideration the committee decided to include these two sizes in the original list, making the 14 sizes now adopted as standard.

The second problem was a more intricate one. The number of sizes now produced by the rolling mills for use in machinery is very large. Almost every sixty-fourth of every inch up to three inches is drawn. This means excessive equipment at the mills and large stocks in the warehouses. If a reasonable number of these sizes could be eliminated or classed as "Specials" and a comparatively few sizes selected as standard or stock sizes, a great saving would thus be effected and a valuable service performed.

In order to get the opinions of leading consumers of shafting for machinery purposes, the committee decided to lay the plan before some 225 large consumers of this material and invite their comment upon its desirability or feasibility and their advice as to the size interval between standard diameters which should be considered. It was explained that it was not intended that the adoption of certain sizes as standard should make it impossible to secure any other size required on special order; but that the general elimination of a great number of the sizes now in use and the consequent greatly increased production of the standard sizes could only tend to a reduction of mill costs and capital invested in manufacturers' equipment and in stocks in warehouses. Both of these savings should have a lowering effect upon the price to the consumer and the problem was, therefore, truly one of conservation.

In the case of machinery shafting the users were equally unanimous in their approval of the plan to standardize sizes, but recommendations as to size interval varied greatly. However, these recommendations, in so far as they were definite and specific enough, were tabulated and a diagram constructed showing the relative popularity of the various size increments for each inch of diameter.

With these data accumulated and sifted down to usable form the committee felt that it was in a position to present its information and preliminary deductions to representatives of other interested organizations. Accordingly, invitations were issued to twelve societies and associations requesting them to consider the proposed lists of standard sizes and to appoint representatives to confer with the committee before its report was finally formulated. The seven organizations listed below responded and the standard sizes which follow have the unanimous approval of these representatives and, as far as can be learned, of their associations.

American Hardware Manufacturers' Association
American Railway Engineering Association
American Supply & Machinery Manufacturers' Association
National Association of Manufacturers of the U. S. A.
National Association of Purchasing Agents
National Machine Tool Builders Association
Southern Supply & Machinery Dealers Association

The committee then considered that it had completed the first part of the work to which it had been assigned, so on January 14 submitted to the Council a progress report in which it recommended the approval and adoption of the following lists of sizes as standard for the Society:

Transmission Shafting:

15/16 in; 1-3/16 in; 1-7/16 in; 1-11/16 in; 1-15/16; 2-3/16 in; 2-7/16 in; 2-15/16 in; 3-7/16 in; 3-15/16 in; 4-7/16 in; 4-15/16 in; 5-7/16 in; and 5-15/16 in.

Machinery Shafting:

Size intervals extending to $2\frac{1}{2}$ in., by sixteenth inches; from $2\frac{1}{2}$ in., to 4 in., inclusive, by eighth inches; from 4 in., to 6 in., by quarter inches.

The Council approved the report and accepted the recommendations.

In the opinion of the committee the adoption of standard sizes of shafting will mean that in the future there will be a gradual elimination of odd sizes from makers' lists and from dealers' stocks, and for new construction only standard sizes would be selected.

Before undertaking the standardization of the shafting formulæ and the dimensions of shafting keys and keyways the committee plans to reorganize itself and add to its membership.

MECHANICAL ENGINEERING
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Editorial Associates on Mechanical Engineering

C. E. Davies, a graduate of Rensselaer Polytechnic Institute, and for several years in production work with the Remington Typewriter Company, Syracuse, N. Y., has joined the staff of MECHANICAL ENGINEERING as one of the Associate Editors. Mr. Davies was in the Ordnance Department at Frankford Arsenal for 15 months during the war, and left the service with the rank of Captain.

E. W. Tree, who has been with the Society during the past year and was formerly an instructor in the Electrical Engineering Department of Brooklyn Polytechnic Institute, has also been appointed an Associate Editor. Of the other members of the Staff, Leon Cammen, for many years Associate Editor, will continue in this capacity and as in the past prepare the Engineering Survey; and C. M. Sames, Associate Editor for four years, will have the direction of the Engineering Index.

A.S.M.E. to Meet in Convention at St. Louis, May 24 to 27

A tentative program for the Spring Meeting is printed in Section 2 of this number of MECHANICAL ENGINEERING. In connection with it, announcement is made of an opportunity to visit the immense hydroelectric plant at Keokuk, on the Mississippi River, illustrations and description of which appear in this number. Particulars regarding the excursion are contained on page 60 of Part 2, or Society Affairs Section, of this issue.

Papers to be presented include several groups upon certain special subjects, such as aeronautics, the appraisal and valuation of property, and foundry practice. One session will be devoted to scientific papers, and another to miscellaneous papers, mainly on power-plant subjects. The St. Louis Local Committee will have a session of their own, with papers of local interest, principally upon new developments in river transportation, and on industrial housing, a large project for which is under way at St. Louis.

Two papers of unusual interest come from Government sources, one of which will be by Lieut.-Colonel H. W. Miller, Artillery Division, U. S. A., who recently contributed the German Long-Range Gun article to MECHANICAL ENGINEERING. Colonel Miller has investigated heavy artillery abroad and will speak on the formidable German defenses on the coast of Belgium. Lieut. E. R. Jackson, Ordnance Department, U. S. A., Tank, Tractor and Trailer Division, will show moving pictures of the transcontinental trip made by a large number of army trucks, an extended account of which was published in the last number of MECHANICAL ENGINEERING.

The Local Committee has arranged several excursions and social affairs, listed in the tentative program, which are most attractive. Members of the A. S. M. E., and their friends, who can do so, are cordially invited to attend.

"Conservation Through Engineering"

Past-Secretary of the Interior, Franklin K. Lane, who upon retiring from that office characterized official Washington as "rich in brains and in character, but poorly organized for the task that belongs to it" has given considerable attention to the engineering features of the work of that department. This is evidenced by the frequent and comprehensive references made to engineering work in the last annual report of the Secretary of the Interior, and by the specially-printed extracts of that report which have been published under the title quoted above.

This report deserves the careful attention of all engineers. The recent coal strike and the attention given it by the Interior Department is covered in considerable detail with pertinent questions asked and answered as to the means of conserving coal and meeting future emergencies of this kind. Under the heading, White Coal and Black, the question of water power is briefly treated. Petroleum from the standpoint of its production from oil shale and its use as fuel and generating power is also discussed with a comprehensive summary. It will be recalled that Mr. Lane was especially active with broad plans for soldier settlement legislation,—it was he who first introduced soldier settlement plans. Other phases of the reclamation and development program are covered in an interesting manner. Conservation Through Engineering is a public document known as Bulletin No. 705. and may be obtained from the Superintendent of Documents, Government Printing Office, Washington, D. C., at ten cents per copy.

A University for the Industries as Well as for the People

The University of Michigan, long a source of help and inspiration to the people of its own state, as well as to its many students and friends in other sections, is now arranging for extensive coöperation with the industrial and technical interests of the state along the lines of scientific research.

A new department of Industrial Research is to be organized in connection with the Colleges of Engineering and Architecture. The department will be under the administration of a director, who will be assisted by an administrative committee of the University and by an advisory board composed of men representative of the industries of the state. Investigators and assistants will be assigned to the Research Department as required, and the work in this department will be open to graduate and undergraduate students under suitable conditions. The industry or group of industries having researches undertaken is to pay for these researches, and the University reserves the right to make public at such times and in such ways as it deems best the results of any work done on any problem by the Research Department. The University is to set aside for the miscellaneous expenses of the department a sum of $10,000 a year, and it is expected that the industries of the state will provide initial funds, in part, at least, for meeting the preliminary expenses incident to the laboratory equipment required for the new undertaking.

This action by the University has followed a report recently made by the Michigan Manufacturers' Association recommending such coöperation. A great deal of credit is also due to the Chicago Engineering Alumni of the University who prepared a report on this subject in 1916 and whose long-sustained efforts to bring the industries into closer relations with the University are now to bear fruit. These Chicago alumni have done a great deal in various directions to advance the cause of research as evidenced by resolutions presented at the last Spring Meeting of The American Society of Mechanical Engineers, largely through their efforts, in which a broad program was outlined for research generally throughout the country, and in which the colleges of the country were an important element.

Annual Volume of Engineering Index to be Issued May 15

The 1919 annual volume of The Engineering Index will be available about May 15th, the earliest date at which it is possible to complete printing. This publication has been compiled from the monthly issues of The Engineering Index which have been a feature of Mechanical Engineering during the year just passed. The items as they appeared from month to month were classified under general headings designating the broad divisions of engineering, but an extended investigation of the merits of different systems of indexing showed that an alphabetical or dictionary arrangement was greatly preferred by the users. Accordingly, in the preparation of the annual this system has been followed. The 12,000 items comprising the index have been entirely rearranged according to this system by a staff of engineers, and while this has entailed many weeks of labor it is believed that the result will fully justify the effort.

Diesel-Electric Drive for Ships

The Diesel engine has regularly been used in submarines as the propulsive power for driving the propeller when on the surface, and also for charging the storage batteries through a generator, thus providing an electric drive when submerged. In the meantime a method for driving the propeller from a prime mover, through the intermediary of an electric generator and a motor, was developed in this country and first applied in the form of a steam turbine-electric drive such as now used on the U. S. battleships.

The many good features of the electric drive for ships, in combination with steam turbines, have been so fully demonstrated that it was to be expected that the same system would be tried in combination with Diesel engines. The Diesel engine, like the turbine, is capable of extraordinarily high economy, and, like the turbine, it should be operated under the conditions which its constructive features demand, rather than under the conditions imposed by the speed limitations of the propeller.

What is said to be the first trial of a Diesel-electric drive for ships is reported in the current issues of the marine papers as being on the yacht *Elfay*, a schooner of 152 ft. length overall, 30 ft. beam and 313 gross tons capacity. The yacht is driven by a 6-cylinder Winton Diesel oil engine rated at 115 hp., at 425 r.p.m., direct-connected to a 75-kw. Westinghouse generator, which in turn is direct-connected to a 9-kw. exciter. The motor for the propeller is rated at 90 hp., at 360 r.p.m. The entire boat is operated and controlled by electricity, no steam being used or required. All the auxiliaries are electric-driven and all movements are controlled from the bridge without having to signal the engine-room.

The yacht is said to make 8½ knots on 7½ gal. of fuel per hour; and since she can carry 2400 gal. of fuel, she is able to run 2000 miles on her propelling equipment alone. Although the *Elfay* is by no means a typical merchant vessel, it is believed that if the new drive proves successful on her it will be extended to purely commercial ships. In fact, consideration is now being given to the application of Diesel-electric power to some of the wooden freight vessels of the Ferris type now offered by the U. S. Shipping Board, where there is not sufficient headroom in the hold for boilers and engines of the usual type. In an article in *International Marine Engineering* for March, the project is outlined for placing Diesel engines on the main deck of the ship, using as many units as are required for the power to be generated, these engines being of the stationary type, but light enough for marine use.

Recent Development in American Aeronautics

The aeronautical show held in New York during the second week of March brought out no very startling and novel developments, but it clearly demonstrated that the aeronautical industry in America is developing along sane and conservative lines.

Contrary to statements repeatedly made in the daily press, the aeroplane and aeronautic-engine plants are neither closing their doors nor dismissing their engineering personnel. On the contrary, they are doing fine work and are gradually placing the industry in the position to which it is entitled in view of the fact that the aeroplane was conceived in this country and made to fly for the first time as a result of the genius and perseverance of American engineers.

In this connection attention may be called to an important publication issued by the director of Air Service, Washington, D. C., namely, a Report on First Transcontinental Reliability and Endurance Test, conducted by the Air Service, U. S. A., in October, 1919. The official conclusions arrived at on the basis of a very careful analysis of all that happened are of unusual interest.

As regards motors, it is stated that on the whole the performance of the Liberty motor can be considered quite satisfactory although one is constrained, after very careful consideration of all the circumstances, to arrive at the conclusion that the Liberty motor cannot run full out for more than 40 hours, though with careful nursing to avoid excessive vibration it will run over 100 hours without overhaul.

A Hispano-Suiza motor should act well and the test showed that with some care the high-compression Hispano-Suiza motor will stand up against fearful strain.

It is not entirely pleasant to find that on the whole the German Mercedes 160-hp. low-compression motor gave a performance which the official report describes as "wonderful." No spare parts were needed and only a few minor adjustments to the magnetos, jets and plug points were made.

As regards planes, the test has shown conclusively that the DH-4 is a very good machine. On the other hand, the SE-5A made a remarkable showing in the test. Although as a single-seater plane it was not designed for the long, continuous flights of a trans-continental trip, it gave less trouble than the DH-4. The Martin bomber, which was the only type of multi-engined machine entered, showed an extremely fine performance and despite its great load kept up with the lighter craft.

In this flight there were several fatalities, the causes of which are carefully analyzed in the report. In general it would appear that while extensive precautions are taken in a test of this nature, it is nevertheless practically impossible to avoid accidents. One of the rules of the test stated that aeroplanes entered must be capable of a speed of over 100 m.p.h. These aeroplanes designed for war purposes are not as safe as the less speedy craft which would be flown for commercial purposes. It is another question whether such a rule should have been made for such a test, as obviously even in war times high-speed aeroplanes would hardly be used for transcontinental flying, except under very unusual circumstances.

The test strongly accentuated the importance of the pilot and demonstrated clearly that he is not merely an aerial chauffeur.

Considering the show and the report of the transcontinental flight, together with the high-altitude flight of Captain Schroeder (of which more is said elsewhere in this issue) as the three outstanding events of March, 1919, one can hardly help coming to the conclusion that aeronautics is quite alive in this country and very gratifying results are being obtained.

The Engineer's Attitude on Military Legislation

Despite the fact that Congress has failed to enact legislation dealing with the subject of military training, and that public opinion seems at least to be divided on the question, the engineers through Engineering Council have gone on record as favoring a sound and effective development of both army and navy. This recommendation of Engineering Council comes through its Military Affairs Committee which was appointed in December, 1919, to consider the relation of engineers to the future military activities of the United States. Col. William B. Parsons is chairman of the committee, which is composed of both civilians and ex-officers of all branches of the service. The committee's recommendations to Engineering Council which were unanimously adopted by the executive committee of that body are in part as stated in the following paragraphs:

We believe it of vital national importance that sound military legislation should be enacted during the present session of Congress. Effective provision for national defense with an adequate trained army and navy sufficient to discharge our national and international obligations is essential to security and stability, which must be present if our country is to go forward in constructive activity and achieve its possibilities as a nation.

The careful selection and training of personnel and their assignment, when reservists, to organized reserve units are vitally important to the efficiency of the technical services of the army and navy, and therefore essential to the proper preparedness of the individuals of the engineering and allied professions and trades for the discharge of their constitutional obligations in national military service.

The full utilization of specially and technically qualified men and specialized industries has proved impossible where an organization was built up only after war had become imminent or had been declared.

We believe national security and stability can be assured only by application of the foregoing principles, in particular the principle of universal military training and the creation of organized reserves, above all in the technical branches. We, therefore, recommend to Engineering Council that the President, and Vice-President of the United States, the Secretary of War, the Secretary of the Navy, the Speaker of the House and the Chairmen and Members of the Military and Naval Committees of the Senate and the House be urged to incorporate the foregoing principles into any bills passed by either body for army or navy organization, and particularly the principle of universal training.

The Future Engineer—A Man of Affairs

Engineering started as an art; then it developed into a science. Later it was realized that the engineering of men was as important as the engineering of things and the science of management came into being. Finally, the management of affairs, of men and things taken together collectively, is receiving a great deal of consideration and there is a general movement in the technical schools and colleges toward the teaching of business administration to engineering students.

How general this movement is has been shown in a recent report of the U. S. Commissioner of Education based on the replies to letters sent out to a number of the larger colleges and universities requesting "a statement of present practice and any change contemplated in courses of study in engineering and commerce." Fifty-five replies were received, a study of which brings out some interesting facts.

Approximately a third of the replies received came from colleges or universities which offer subjects in economics and business administration in connection with their engineering courses. In general the curricula provide business training in greater or lesser amounts for engineers who expect to enter positions concerned with the management or administration of manufacturing, construction, and transportation enterprises, which demand a knowledge of business as well as of scientific and engineering principles.

There are several institutions in which the combined business and engineering course is already well developed. For over 20 years Stevens Institute of Technology has given its students instruction in the commercial or business side of engineering. Dartmouth College has offered for four years a course in engineering management. A unique feature of this course is the large requirement in outside reading covering thirty or more books on the subject. The University of North Dakota has offered for three years a course in general engineering, providing about 60 per cent of the work along fundamental subjects in sciences, mathematics and technical engineering, and about 40 per cent in subjects relating to both business and engineering careers.

Massachusetts Institute of Technology gives a course in engineering administration which combines instruction in general engineering studies and in the methods, economics and law of business. The course includes (1) the instruction common to all courses, in literature, language, and history, and in chemistry, physics and mathematics; (2) a choice of engineering studies classified under three options: civil engineering, mechanical and electrical engineering, chemical engineering; and (3) a selected group of subjects in business and economics.

Other colleges which do not cover as much ground in their prescribed course, offer these subjects as electives or, in a few cases, in a special fifth-year course devoted to business administration.

There is only one institution reported in which no course is offered in either commercial or industrial engineering. A few commercial schools include engineering subjects in their courses.

The balance of the reports come from institutions which although they do not now offer a combined course, nevertheless are in favor of doing so as soon as they feel that the demand is great enough. Some of them are now at work on new engineering curricula covering a four, five, or six-year combined course. Columbia University, for instance, plans to have in the near future a course in manufacturing and industrial engineering, and Tulane University, New Orleans, now has under consideration a revision of its engineering curriculum to provide proper business training for engineers.

Scientific American Supplement Now Issued as a Monthly

The *Scientific American Supplement*, edited by A. Russell Bond, is now issued as the *Scientific American Monthly* and has been greatly broadened in scope. Besides containing important announcements of distinguished technologists appearing in foreign as well as domestic publications, it furnishes translations of the complete texts of significant articles in European books, etc., and has several departments to which various organizations contribute. The National Research Council and the Bureau of Standards each supply material for a department, and a similar section is to be edited by the U. S. Bureau of Mines. The American Society of Mechanical Engineers furnishes regularly a review of important articles in the field of mechanical engineering and a similar service covering the field of mining and metallurgy is being rendered by the American Institute of Mining and Metallurgical Engineers. Reviews are also being given in the fields of electrical engineering and industrial chemistry. The journal is unique in that it carries no advertising, all the pages being text pages. While it is realized that the rapidly rising cost of paper and printing may make it impossible to issue a publication with 96 pages of text, such as this journal contains, from the income received solely from subscriptions, the attempt is nevertheless being made to conduct the journal on this plan.

The *Scientific American Supplement* was founded in 1876 at a time when there was aroused by the Centennial Exposition a great public interest in science. It was established to meet the growing demand for information of a higher technical character than could properly be published in the more popular *Scientific American*.

Major Schroeder's Record Altitude Flight

Notes on Major Schroeder's Accomplishment—Technical Difficulties Encountered—Military Value and Commercial Uses of Supercharger

On February 27, Major R. W. Schroeder, chief test pilot of McCook Field, Dayton, Ohio, drove an aeroplane to a higher altitude than has ever before been reached. Official figures show that an altitude of 36,020 ft. was attained and that the official record of 30,300 ft. reached by Rolland Rholfs on July 30, 1919, and the unofficial record of 33,137 ft. credited to Adjutant Casale, the French pilot, were broken.

The public is familiar with the story of how Major Schroeder set out to reach the altitude of 40,000 ft.; of his battle against a temperature of 67 deg. below zero and a wind of 100 m.p.h.; of how his oxygen gave out; of his fall of five miles; and of his miraculous landing at McCook Field. Further information regarding the flight, prepared for MECHANICAL ENGINEERING by Col. Thurman H. Bane, Commanding Officer of McCook Field and released by the Air Service, is given below.—EDITOR.

MAJOR SCHROEDER'S successful altitude flight was the result of a long series of important tests in engineering development by the Engineering Division of Air Service, U. S. A. This series of tests has disclosed problem after problem which had to be overcome in some manner before further advances could be made. Some of these troubles were:

a Obtaining a suitable propeller

b Keeping the mixture ratio of the carburetor constant throughout a wide range of altitude and therefore varying the differences in proportion between the throat of the carburetor and the atmosphere surrounding it

c Delivering fuel to the carburetor against its varying pressure

d Cooling at high altitude and raising the boiling point of the water

e Providing a drain valve to let the water out of the radiator at high altitude in case the engine should stop, so that the engine and cooling system would not be ruined by the water freezing; and further, of so arranging the valve that it would not itself freeze and thus become inoperative

f Securing goggles which would not freeze over in the intense cold at great heights; (such goggles were invented and designed by Major Schroeder)

g Developing a special instrument to show the pilot how to handle his exhaust bypass gates, or, in other words, how to control the supercharger pressure in his carburetors without the need of making any calculations.

The Engineering Division has been most fortunate in having Major Schroeder to pilot the airplane throughout the preliminary supercharger development tests which were made, because, in addition to being a surpassingly good pilot, he is an excellent engine mechanic and is one of the few pilots who can really sit in an airplane and know what an engine is doing and what it needs. In this way he has helped the development immensely.

Considerable trouble has always been encountered from preignition when running with a supercharger, due to the fact that the air delivered to the carburetor is at very high temperature. Future designs of superchargers will provide additional intercooling between the compressor and the carburetors. The fuel-feed system, prior to Major Schroeder's flight, had operated quite satisfactorily, but in spite of this fact it was necessary for Major Schroeder to close the vents in his gasoline tanks and pump some pressure in them with a hand air pump in order to help the fuel pumps deliver the fuel at the extreme altitudes.

To reduce the preignition which it was expected would be encountered on this flight, a specially prepared fuel was provided by Mr. Thomas Midgeley, Jr., who has been developing "anti-knock" fuels for Mr. Charles F. Kettering, Mem. Am. Soc. M. E. This fuel proved to be of great assistance in this flight as it caused the motor to run much more smoothly than it would otherwise have done.

The supercharger used by Major Schroeder was the old original General Electric supercharger designed by Dr. Sanford A. Moss, Mem. Am. Soc. M. E., and originally tested on Pike's Peak in 1918; and it is not surprising, therefore, that no good means had been provided for blowing off the exhaust gases which issue from the turbine. The exhaust gas has bothered the pilot to a certain extent, due to the fact that it sweeps past his face. No way has been found to date to entirely carry the exhaust clear of the occupants of the machine. On this record flight it seems that the gases expanded more rapidly as they issued from the turbine in the thin air at great altitude and that they swept past the pilot's face in even larger volume. Judging from the doctor's report, it seems that the carbon-monoxide poisoning gave Schroeder more trouble than the lack of oxygen.

In military work an automatic oxygen-feed apparatus is provided for the pilot which regulates the amount of oxygen in proportion to altitude so that it is not necessary for him to think of making any adjustments. Major Schroeder had been in the habit of using a simple rubber tube extending from the neck of the oxygen flask to his mask in such a manner that he could adjust the flow by hand, as he has often had trouble with the oxygen pipe freezing up and flow stopping at high altitudes. On his record flight he knew he would be up for a long time, and he desired to use the automatic apparatus as long as he could. He believed it would work to about 29,000 ft., and therefore took one bottle of oxygen, connected through the automatic oxygen feed and one connected direct. However he found that the automatic apparatus did not work at all and he therefore had to start using his emergency bottle at about 18,000 ft. and realized that it might run short, although he thought it would last long enough for him to accomplish his record. Nevertheless, due probably to the large amount of exhaust gas he was breathing, Major Schroeder had to use an excess amount of oxygen, which, of course, resulted in his reaching the end of his supply sooner than he expected.

It is noteworthy that the instrument which shows the pilot what pressure his supercharger is delivering to the carburetor showed a pressure something close to that of sea level, even when he was at the highest point of the flight. The operation of the supercharger was excellent throughout the flight and it was found to be in good condition afterward.

Major Schroeder states that he actually reached warmer temperature at the top of his climb. The coldest temperature record was about −67 deg. fahr. and two or three thousand feet higher, at the top of his climb, the temperature was 4 deg. higher. He encountered the usual strong west wind which he has in every case encountered at altitudes above 25,000 ft. He believes the velocity of this wind to be close to 175 m.p.h., judging by the rate at which it drifted his machine eastward, even though he was headed west and climbing at an extraordinarily high air speed due to the use of the supercharger. It is to be regretted that figures on these speeds cannot be given for publication.

It is an interesting fact that after a certain low temperature is reached the exhaust gases issuing from the engine become snow white from the freezing of the vapor in them, and from that time on long, white clouds formed by this exhaust are visible from the ground on a clear day such as the one on which Major Schroeder's flight was made. This results in ice forming on all the wires and struts coming in contact with the stream of the exhaust.

When Major Schroeder's oxygen supply finally failed, he raised his goggles in order to see more clearly in his endeavor to "coax" some more oxygen from one or the other of his tanks, and at this moment unconsciousness suddenly overtook him—but not before he reached for his switch and put the machine into a spiral. He intended to make one steep spiral which would bring him down to about 20,000 ft. above the ground, where he expected to

recover; but, although he believed after his fall that he had succeeded in doing this, as a matter of fact the plane fell into a "shot pigeon" down to about 3000 ft. above the ground, where Schroeder regained consciousness, "righted" the plane and, although he was still semi-conscious and could scarcely see at all due to the chilling of his eyes, had the presence of mind to open the vents in his gasoline tanks so that the engine would continue to get fuel and run. It happened that he succeeded in getting only one switch instead of two which are present in all Liberty ignition systems, therefore his engine had been running practically wide open throughout the fall. This kept the water from freezing in the cooling system and gave him the use of the engine after his recovery from the fall.

The daily papers have given the details of his marvelous landing in spite of his almost total blindness, so nothing will be said here about that; however, it is of interest to note that the gasoline tanks which probably had a plus pressure of several pounds in relation to the surrounding atmosphere at the top of the climb had collapsed,—that is, three out of four of them had collapsed, one of them almost totally, due to the fact that at the bottom of the fall conditions had changed so that there was a minus pressure inside of several pounds. This is why it was necessary for Major Schroeder to open the vents in the tanks in order to be able to deliver fuel to the engine to get to a suitable place to land.

The military value of the supercharger will be very great. It will greatly increase the speed of airplanes at high altitudes and enable them to go much faster than they can near the ground. It will be useful for photography at extremely high altitudes, because the photographer will not be hampered by attack if the plane goes high enough. An airplane with supercharged engine will be valuable to carry dispatches or a high-ranking officer over great distances in a very short time. Superchargers, when applied to heavy bombers, will enable this type of machine to reach a ceiling well above enemy anti-aircraft gun fire, and in fighting planes superchargers will greatly increase speed and climb.

Commercial use of superchargers will be to enable heavy passenger- or express-carrying airplanes to climb over the highest mountains or over thunderstorms with the use of comparatively low-powered and low-priced engines; without the supercharger, very large engines would have to be installed in order to have sufficient power to sustain the airplane at high altitudes. This is largely unnecessary if superchargers are used. It is felt that passenger-carrying airplanes can be provided with a supercharger and an airtight cabin for the passengers so that the supercharger can keep the air in this cabin at a density and temperature which will make it practically comfortable for all passengers, and at the same time the airplane can fly at extreme altitudes at very much greater speeds; and speed, after all, is one of the chief advantages of air travel over other kinds.

James Waring See

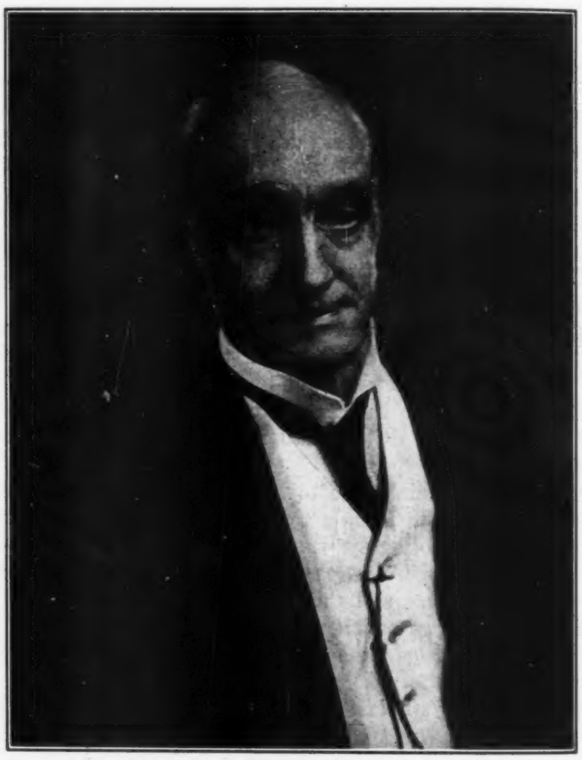
James Waring See, a charter member of the A. S. M. E. and a widely known engineer, died at his home in Hamilton, Ohio, on January 31, 1920. Mr. See was better known to the readers of mechanical journals as "Chordal," a pen name used by him for much of his writing. About 1880 he began a series of articles in the *American Machinist* under the title of "Extracts from Chordal's Letters." These articles were of the shop by a shop man and it would be difficult for a person of the present generation to understand the deep impression which they made on the mechanical men of the country and the widespread interest which they created.

Mr. See was born in New York City on May 19, 1850. He received his earliest education in a country school at Rutland, N. Y., though he later attended school at St. Louis, Arcadia and Springfield, all in Missouri.

At the outbreak of the Civil War Mr. See was employed in the Springfield military hospital as an assistant in the dispensary and in the operating ward. After the battle of Carthage he was made telegraph messenger to the Federal forces in and around Springfield. Upon the ending of hostilities Mr. See served an apprenticeship as machinist at the Springfield Iron Works and it was there he laid the foundation for his future career. At the completion of his apprenticeship he found employment in various shops located from St. Louis to Yankton, S. D., eventually settling at Omaha, Neb., where he started a shop of his own.

The story is told of him that being disappointed in a lathe he bought from the Niles Tools Works he wrote to that firm to the effect that if he could not design a better lathe he would eat it. Alexander Gordon, head of the Niles works, testily replied that if he was able to design a better lathe than the one in question, he wished he would come to Hamilton and do it.

Long after Mr. Gordon had forgotten the incident there appeared in his office a tall, lanky individual who said with a drawl, "My name is See and I came up here to design that lathe for you." He was put off with one excuse after another until in disgust he appropriated an empty drawing board and did design a lathe that made Mr. Gordon sit up and take notice.



JAMES WARING SEE

He was at once employed by the Niles Works, filling positions as foreman, chief draftsman and chief engineer, respectively. In 1876 Mr. See opened an office in Hamilton, Ohio, as a consulting mehanical engineer and his keen insight into mechanical matters soon brought him a wide practice in connection with some of the largest machine establishments in the United States and Europe.

With the invention of the telephone, Mr. See became greatly interested in its practical workings and was the inventor of several valuable devices connected with central-station apparatus. In recognition of his work he was made an honorary member of the Telephone Exchange Association. For a time he was editor of the *Telephone Exchange Reporter*. He built the first telephone line in Hamilton. Also in connection with Alexander Gordon and James K. Cullen, he built an electric-light plant at the Niles Tool Works, the first in Hamilton.

As Mr. See's business increased, he became a patent attorney and as such developed an enviable reputation as an expert in patent litigation, and was called on to give expert testimony in more than three hundred cases.

By appointment of Governor Campbell, Mr. See acted as one of the commissioners for Ohio to the World's Fair held at Chicago in 1893.

Government Activities in Engineering

Notes Contributed by The National Service Department of Engineering Council[1]

Agreement Expected on Water Power Bill

As stated in MECHANICAL ENGINEERING for February the Water Power Bill has been in the hands of a committee composed of members from both the House and Senate. This was for the purpose of settling on points of difference, and while it was expected that not more than two weeks would be occupied in getting the bill through this Joint Conference Committee, nevertheless on March 9th. when the committee adjourned for a period of two weeks, there still existed two important points of difference. This adjournment was taken to await the return to Washington of Representative Taylor of Colorado and to permit Senators Jones and Smoot to devote some time to the Merchant Marine and Executive Bills, both of which are now pending.

These differences pertain to license charge and recovery and the proposal to have an army engineer as an executive secretary. The strong opposition to this latter plan will probably result in the placing of a civilian in that office with the authority to have an engineer officer detailed to assist in the work. Those in immediate touch with the status of the Water Power Bill regard the situation as very satisfactory and it is anticipated that a committee agreement may be shortly expected. The power project for Great Falls on the Potomac River, which carries an appropriation of $25,000,000 and which was placed in the bill as a rider by the Senate, was eliminated in the conference. No further details are at present available concerning the other items of the bill.

New Board of Surveys and Maps Meets to Perfect Organization

The various developments leading to the creation of a new Board of Surveys and Maps which will coördinate the many map making agencies of the Government were presented in considerable detail in MECHANICAL ENGINEERING for February (p. 134). Since then the members of the Board have met with representatives of non-federal organizations for the purpose of determining the policy of the new Board and the manner in which it shall function. This meeting, held on March 9th, was called by the chairman of the Board, O. C. Merrill, Chief Engineer of the Forest Service, Department of Agriculture.

The report of the committee of representatives of the non-federal organizations was presented by M. O. Leighton of Engineering Council, who stated that while efficiency and economy in centralized mapping operations was most commendable, there might be certain occasions when it would be more advantageous for a particular department to do its own mapping. The consideration of the Board in such cases would have to be in a large degree judicial and representatives of the interested department should be disqualified from participating in decisions affecting that department. It was further suggested that a plan should be adopted by which coöperating non-federal agencies could have a voice in the determination of the manner and the place of disbursement of their contributed funds.

The report of this non-federal committee also commented upon the following special features of the conference report: the preparation of skeleton maps of various scales; the methods of distribution as affected by the size of editions, costs, etc.; and the preparation of maps suitable for educational institutions. The need of a general topographic map of the United States and the means by which its preparation may be expedited was covered from the highway, railroad, and military standpoints by governmental and military officers.

The Patent Bill

Due much to the efforts of Edwin J. Prindle and his colleagues, the Nolan Patent Bill (H. R. 11984) was put on the House calendar for March 5th, and was passed on the same date. Mr. Prindle is chairman of the Patent Committees of both Engineering Council and National Research Council. It will be recalled that extensive hearings were held before the House Patents Committee so that the case presented to the Rules Committee consisted in urging immediate consideration of the Bill.

About sixty engineers, members of the Founder Societies or representatives of organizations using the Patent Office, supported Mr. Prindle. When the hearing was over, the chairman of the Rules Committee told these men that it had been the most satisfactory hearing held by his committee in over ten years and that the thorough disinterested manner in which the engineers had presented their case assured early action in the House. This assertion was borne out when the House passed the bill a few days later. The bill is now before the Senate Patents Committee who intend to hold short hearings.

Administering the New Land Leasing Law

The provisions of the Land Leasing Bill, to which reference was made in the last issue (p. 200), went into effect when the President signed it on February 26th. Its administration was handed over to the Interior Department, and to correct the misunderstandings that have arisen in connection with this new law, that department immediately prepared a set of regulations which have now been approved by the Secretary of Interior and are available for distribution.

Inquiries received indicate that many had gained the impression that leases on proven oil lands of great value were to be had merely by the filing out of an application prior to anyone else. The regulations point out that this is not the case, because proven oil lands of the Government are largely covered by claims of various kinds that have been in litigation for some time and which must be submitted for adjustment within six months. Until such claims are acted upon none of the lands can be leased and then only to the extent to which such claims are rejected. Further, if the Government grants a lease for their oil or coal land, except under the relief sections or as the result of a permit, it will only be by competitive bidding of which ample notice will be given to the public.

The only part of the act which is self-operative and not subject to the regulations of the Department is the section which provides for securing a preference right for oil prospecting permit by posting a notice on the ground. This applies only to lands not in the geologic structure of a producing oil field.

Government to Develop Inventions

In order that the public, the industries, and the various departments of the government may obtain the full benefit of scientific inventions and patents of departmental employees, a bill has been introduced by the Senate Committee on Patents, proposing to give the Federal Trade Commission authority to arrange for the development of useful inventions, patents, and patent rights in the broadest way. This procedure is to be under such regulations as the President shall prescribe.

The Commission is authorized to collect fees and royalties for licensing the inventions, patents, and patent rights in such amounts as the President may direct and to deposit these in the United States Treasury; the necessary percentages however may be reserved for the remuneration of the inventors of meritorious ideas. The appropriations of Governmental departments are made available for the payment of fees charged in connection with the granting of patents under this Act.

[1] Engineering Council is an organization of national technical societies created to consider matters of common concern to engineers as well as those of public welfare in which the profession is interested. The headquarters of Engineering Council are located in the Engineering Societies Building, 29 West 39th Street, New York City. The Council also maintains a Washington office with M. O. Leighton, chairman of the National Service Department, in charge. This office is in the McLachlen Building, 10th and G Streets, Washington, D. C. The officers of Engineering Council are: J. Parke Channing, Chairman; Alfred D. Flinn, Secretary.

NEWS OF THE ENGINEERING SOCIETIES

Meetings of The American Institute of Mining and Metallurgical Engineers, the American Institute of Electrical Engineers and the Engineering Society of Western Massachusetts

American Institute of Mining and Metallurgical Engineers

The annual meeting of the American Institute of Mining and Metallurgical Engineers was held in New York, February 16 to 20. The retiring president, Horace V. Winchell, outlined the civic activities of the Institute for the year. The new president, Herbert C. Hoover, an abstract of whose address was published on p. 194 of the March issue of MECHANICAL ENGINEERING, spoke on the national problems in which engineers are directly concerned.

The leading technical feature was a conference of coal operators from all over the country, who assembled to discuss the stabilization of the coal industry. At the opening of the conference, President Hoover, at whose suggestion it was called, outlined a program of study and work for the Institute and a constructive plan for the better working of the bituminous coal industry. Dr. Van H. Manning, Director of the Bureau of Mines, talked on Problems of the Coal Industry. Dr. George Otis Smith, Director of the Geological Survey, in Fluctuation of Production of Coal—Its Causes and Effects, presented a statistical analysis of the rate of output over a period of years, indicating the relative effect of shortage of transportation, shortage of labor, lack of market and other factors in producing intermittency in the operation of coal mines. H. H. Stoek, professor of mining at the University of Illinois, discussed the Storage of Bituminous Coal and Its Possibilities of Stabilization. Transportation as a Factor in Irregularity of Coal Mine Operations, by S. L. Yerkes, vice-president, Grider Coal Fields Co., Birmingham, Ala., contained exact data as to the effect transportation facilities have on coal production, use of cars for storage, effect of more equipment, effect of lower rates in spring and summer, reduction of cross hauling, and long hauls by railroads of their own coal.

Numerous papers of scientific interest were presented at the technical sessions on Iron and Steel, Non-Ferrous Metallurgy, Milling and Smelting, Oil and Coal, and Industrial Organization. P. W. Bridgman described an experiment in one-piece gun construction. During the war, the Navy undertook the construction of an experimental gun embodying features designed to lessen the cost and time of production. It was demonstrated by actual construction and firing tests that a gun could be made from a single forging, producing the required distribution of internal stresses by a preliminary application of hydrostatic pressure so high as to strain the material considerably beyond its yield point. The procedure was to start with a single forging of approximately the dimensions of the finished gun, subjected to internal pressure in one or more stages, depending on the external shape, high enough to stress the metal permanently and thus to raise the elastic limit by producing compression in the inside layers and tension in the outside layers. The technique of controlling the pressures required, which were of the order of 100,000 lb. per sq. in., rested chiefly in employing a packing which automatically became tighter at higher pressures.

Tensile Properties of Boiler Plate at Elevated Temperatures was presented by H. J. French. At the request of a committee of the Engineering Division, National Research Council, a study was undertaken of the properties of boiler plate at various temperatures up to about 900 deg. fahr. Tests were made of ½-in. plates of firebox and marine grades. The test specimen was heated by means of an electric tube furnace, two spiral resistors in series being used. In both grades of plate, increase in temperature from 70 to 870 deg. fahr. was accompanied by distinct changes in strength and ductility. The tensile strength at first decreased a few thousand pounds per sq. in., reaching a minimum at about 200 deg. fahr. This was followed by an increase up to about 550 deg. fahr., where the tensile strength reached a maximum about 10 per cent greater than the normal room temperature, after which another and final decrease occurred. The percentage elongation in 2 in. decreased rather slowly up to about 200 deg. fahr., after which it dropped more rapidly, until a minimum was reached at about 470 deg. fahr. The reduction in area had a minimum at a slightly higher temperature than the elongation. The proportional limit at first increased slightly and showed a maximum in the neighborhood of 400 deg. fahr. for the firebox plate and the highest values between 200 and 300 deg. for the marine plate.

Of striking importance were also the following: Intercrystalline Brittleness of Lead, by Henry S. Rawdon; Blast-Furnace Flue Dust, by R. W. H. Atcherson; Critical Ranges of Some Commercial Nickel Steels, by Howard Scott; the Coefficient of Expansion of Alloy Steels, by John A. Mathews; Physical Changes in Iron and Steel Below the Therman Critical Range, by Zay Jeffries.

The American Institute of Electrical Engineers

The eighth midwinter convention of the American Institute of Electrical Engineers was held in New York from February 18 to 20. A feature of uncommon interest was a symposium on super-power plants and transmission for the Northeast seaboard zone. W. S. Murray, consulting engineer, New York City, explained that the super-power plan provided a means by which a present estimated machine capacity of 17,000,000 hp. in a region between Boston and Washington and inland from the coast 100 to 150 miles, now operating with a load factor not exceeding 15 per cent, could be lifted to a load factor of more than 50 per cent and possibly 60 per cent, and a means by which, conservatively speaking, one ton of coal would do the work of two or three. The railroads within the above zone and those carrying coal into that zone would thereby be relieved of transporting one-half the amount of coal required for power and lighting purposes. That is, the value of machine capacity from a utilization standpoint would be increased from threefold to fourfold and coal resources for the purposes named be conserved twofold. It has been estimated that a saving of $300,000,000 a year would result from the establishment of this super-power system. In one of the other contributions it was pointed out that generating stations of from 200,000-kw. to 300,000-kw. capacity, employing generating units of from 50,000-kw. to 75,000-kw. capacity, would involve no difficulties of design, construction or operation, and that from such stations a steam consumption rate of 10 lb. per kw-hr. or less and a total station rate of less than 1½ lb. of good quality coal per kw-hr. output should be obtained. Hope was expressed that a bill appropriating money for this national need would be presented before Congress by July 1, otherwise the plan would have to be financed by backing it with Government bonds or interstate or private capital.

The Measurement of Projectile Velocities, by Paul E. Klopsteg, physicist, Leeds and Northrup Co., and Major Alfred L. Loomis, Ordnance Department, was the title of a paper discussing the requirements imposed by proving-ground practice upon a chronograph intended for general ammunition testing. The number of Boulangé instruments in possession of the Ordnance Department was entirely insufficient for testing the immense quantities of ammunition contracted for by the Government during the war, and a new type of instrument was accordingly developed and adopted as standard ordnance chronograph, which was designated "Aberdeen chronograph." It is an assembly of standard parts with a few necessary special ones and rapid production was thereby made possible. Many comparative tests as to accuracy were made during the process of development, and invariably the average dispersion with the Boulangé chronograph was found to be from two to four times as great as with the Aberdeen. In routine firing, the three Aberdeen chronographs tested agreed within one or two feet per second on a velocity of 1700 ft. per sec., and only rarely

did the maximum dispersion at this value become as great as 5 ft. per sec.

The economic and sociological aspects of daylight saving were discussed by Preston S. Millar, who stated that this wartime measure had reduced the total output of certain central stations and of one gas company by about 3 per cent during the seven summer months, reduction in output for lighting alone having averaged 8 per cent. Applying these data to the country as a whole, Mr. Millar estimated an annual saving by the public of $19,250,000 in expenditure for artificial light and a reduction of about 495,000 tons per annum in consumption of coal. On the other hand, he estimated the economic losses resulting in consequence of interfering with agriculture, dairying and truck gardening at over $1,000,000,000. He therefore concluded that the very obvious solution of the problem appeared to lie in diversification of hours of industry. Since advancement of clocks, while serving the interests of one part of the population, has proved so disadvantageous to another part as to compel return to correct time, it seemed obvious, Mr. Millar pointed out, that those who benefit by advanced time in summer should adjust their habits as desired without disturbing the practice of the remainder of the population.

Participation of engineers in public affairs was urged by President Townley in his address. A sub-committee of the Standards Committee of the Institute submitted a proposal to standardize symbols for use in electrical diagrams, and offered for criticism and approval a tentative list of the more fundamental symbols. A dinner-dance at Hotel Astor constituted the social function of the convention.

Engineering Society of Western Massachusetts

The February meeting of the Engineering Society of Western Massachusetts was held on February 24 at the High School of Commerce Auditorium, State Street, Springfield, Mass. Mr. W. E. Hodge, who is deputy in charge of street lighting in the city of Springfield, spoke on Street Lighting as an Engineering Problem, and Mr. John L. Harper, vice-president and chief engineer of the Niagara Falls Power Co., spoke on Niagara Falls Power Developments. Both lectures were illustrated by slides.

Government Issues Special Ruling on Reinstatement of War Risk Insurance

Under a new and very liberal ruling, of far-reaching importance to millions of former service men, War Risk (term) Insurance, regardless of how long it may have been lapsed or canceled, and regardless of how long the former service man may have been discharged, may be reinstated any time before July 1, 1920.

The only conditions to be met are: (1) The payment of two monthly premiums on the amount of insurance to be reinstated; and (2) The applicant must be in as good health as at the date of discharge, or at the expiration of the grace period, whichever is the later date.

The new ruling is the most important liberalization of War Risk Insurance since the passage of the Sweet bill, and is designed for the special benefit of service men who failed to reinstate their insurance prior to the new law, and who have been dischargd for more than 18 months.

Ex-service men may still reinstate their lapsed term insurance at any time within 18 months following the month of discharge by complying with the same conditions. Within three months following the month of discharge reinstatement may be made by simply remitting two months' premiums without a formal application or statement as to health.

Reinstatement may also be made after 18 months following discharge, as follows: If the insurance has not been lapsed longer than three months by complying with the conditions outlined above. From the fourth to the eleventh month, inclusive, after lapse, by complying with the same conditions, and in addition submitting a formal report of examination made by a reputable physician substantiating the statement of health to the satisfaction of the Director of the Bureau.

War Risk (term) Insurance may be converted into United States Government Life Insurance, now or at any time within five years after the formal termination of the war by proclamation of the President, and such Life Insurance, including Ordinary Life, Twenty Payment Life, Thirty Payment Life, Twenty Year Endowment, Thirty Year Endowment, and Endowment at Age of 62, may now be paid in a lump sum at death, if such method of payment is designated by the insured.

Annual Report of the A.I.M.E.

In the report of the president of the American Institute of Mining and Metallurgical Engineers for 1919 it is gratifying to note the establishment of the Robert W. Hunt Prize for the best paper on the subject of iron and steel presented to the Institute for publication. Rules for this prize have been adopted and a medal is being designed by the distinguished artist, Mr. Emil Fuchs. Two bronze tablets have been erected at the headquarters of the Institute, one in memory of Dr. James Douglas and the other commemorative of the American Institute of Metals which was affiliated with the A. I. M. E. in the year 1918.

The Institute has also taken an advanced stand with regard to professionalism and established a precedent worthy the attention of other professional organizations in the expulsion of members believed to be unworthy the honor or privilege of membership. The report states that two members have had the privileges of membership withdrawn—as many as during the past six years—and comments as follows: "If an engineer is unworthy because of his lack of integrity, it is better that he be expelled forthwith, and members are urged for the good of the profession to bring to the attention of the Directors any cases of unprofessional conduct on the part of A. I. M. E. members. We believe that the increase in number of cases reported this year is due to the establishment by the members of a higher qualification for membership, and therefore a greater appreciation of the honor and responsibilities of membership."

TIGHT-FITTING BOLT THREADS

(Continued from page 224)

In conclusion it may be stated that the tests would seem to indicate the following:

1 The cause of stripped threads is lack of room into which the metal can flow

2 The pitch diameter should be the same in both threads

3 The lead should be the same

4 The thread angles should differ by not more than 10 deg.

5 The limits for the inside diameter of nut need not be adhered to closely, as the inner part of the nut thread exerts very little, if any, holding power.

6 The outside diameter of plug and pitch diameter of both plug and nut are important and should be adhered to fairly closely.

DISSIPATION OF HEAT BY SURFACES

(Continued from page 232)

of 0 deg. Then, since the watts dissipated varies directly with the temperature excess for a constant air velocity, it is seen that about 45 per cent more heat will be dissipated per degree under the above conditions of air velocity and heat supplied for an angle of incidence of about 42 deg. than for either perpendicular or parallel incidence. It is further seen that the least heat will be dissipated for 90 deg. incidence or when the coil is parallel to the air stream.

Tests were also made for perpendicular incidence of the air stream for various positions of the coil about its axis. No noticeable difference was observed other than what might well be ascribed to experimental error. This is quite significant since it shows the factor of importance to be the relative position of the axis of the coil in the air stream and not the relative position of the coil about its axis. Such a condition is quite likely to hold for all objects completely within the air stream.

VENTURI-METER CALCULATIONS

(Continued from page 220)

$P_1 - P_2$, that is, actual manometer readings. Interpolation could then be resorted to, and by dividing the value of $Q\sqrt{T_1}$ found in the ordinate by the square root of the inlet temperature the flow in cubic feet of free air per minute could be obtained. The accuracy would depend upon the care taken in the interpolation. It was generally within 2 per cent, however, which was sufficient to answer the purpose for which this set of curves was devised.

CALIBRATION

After consideration and trial of several methods of calibration, it was decided to check the meter against thin-plate orifices, using the empirical formula

$$Q = \frac{405A(P_1^2 - P_2^2)^{0.48}}{\sqrt{T}} \qquad [9]$$

where Q and T are the same as before; A is the area of the orifice in sq. in.; P_1 is the pressure in lb. per sq. in. abs. in front of the orifice; and P_2 is the pressure in the same units beyond the orifice.

This formula, like formula [2], is due to Mr. Reynolds, and has been checked by him by means of a large number of very accurate experiments. Three orifices were used, having diameters of 3/8 in., 1/4 in. and 0.191 in., respectively. All the plates were 1/16 in. in thickness and made of brass.

The results of this calibration are shown in Fig. 2. The coefficient seems to decrease with an increase in flow. This is not in accordance with the results obtained by several other investigators, but the orifices were later checked up and further runs made with substantially the same results. Another calibration was made after more than a year of operation of the meter, and, despite some slight corrosion and roughening of the walls, the coefficient was found to be very nearly the same. It is the writer's opinion that for most experimental work one would be very safe in assuming the coefficient of a carefully constructed venturi meter when metering compressed air to be practically unity, providing the ratio P_2/P_1 was not less than 0.90.

TABLE 1 VALUES OF $f(P_2/P_1)$ FOR VALUES OF P_2/P_1 FROM 1.00 TO 0.90

$\frac{P_2}{P_1}$	$f\left(\frac{P_2}{P_1}\right)$	$\frac{P_2}{P_1}$	$f\left(\frac{P_2}{P_1}\right)$
0.90	0.1600	0.97	0.0917
0.91	0.1534	0.98	0.0753
0.92	0.1456	0.985	0.06535
0.93	0.1369	0.99	0.0535
0.94	0.1276	0.995	0.0370
0.95	0.1170	0.9975	0.02688
0.96	0.1057	1.0000	0.00000

MANOMETERS

As stated before, it was necessary to use two manometers, one filled with water and the other with mercury. This was necessary in order to read accurately values of ΔP from about 11 lb. per sq. in. to 0.10 lb. per sq. in. A valve and piping arrangement with which it was possible to quickly change from one manometer to the other while under pressure, and at the same time keep the liquid in the manometers from being blown out, is shown in Fig. 3. Its operation is apparent. It is necessary, however, to be sure that the valves connecting the two legs of each manometer are *open* when making any change of valves Nos. 1, 4 or 5, or whenever valves Nos. 4 and 5 are closed, and also that valve No. 2 remains *open* at all times when the water manometer is not in use.

It was found that rubber washers cut from soft sheet rubber made the most satisfactory packing for the stuffing boxes on the air, water and mercury ends of the manometers. Brass stuffing boxes and U's were used, excepting on the lower end of the mercury manometer, where wrought iron was used. Glass tube 3 mm. outside and 1 mm. inside diameter was found to be satisfactory. At first an attempt was made to make the manometers from a single piece of glass bent into shape, but it was discovered that the internal strains set up by the heating were so great as to render the tubes unreliable when used at this pressure.

In the final set-up it was necessary to replace the 1/8-in. piping which connected the venturi meter with the manometers with 1/2-in. piping, and to provide small water traps or pockets at the point where these pipes were connected to the venturi meter. This was done in order to prevent water, which was frequently in the compressed air, from working its way over into the piping and even into the manometers, and thus rendering the readings inaccurate. A large number of experimental runs, otherwise perfect, were spoiled before this fact was discovered.

The total drop in pressure across this venturi tube for rates of flow under 100 cu. ft. per min. was only a fraction of a pound per square inch, while at 200 cu. ft. per min. it was only about 2.5 lb. per sq. in. when P_1 was 100 lb. per sq. in. gage. At rates of flow greater than this, however, the drop increased rapidly.

PHYSICAL BASIS OF AIR-PROPELLER DESIGN

(Continued from page 219)

mediate line undoubtedly represents different types of flow on the two parts of the aerofoil. This is possible because of the center support which divides the aerofoil into two parts. At the point of discontinuity corresponding to the second critical speed the lift reading becomes unsteady and the flow phenomena become unstable and jump from one type to another until the new form is established. Fig. 12-*A* shows the unstable flow of the transition, and Figs. 12-*B* and 8 show the flow of the final low-drift régime.

The discovery of this second critical speed is one of the novel and significant features of the experiments. Simultaneous observation of the balance and the flight vortices made the discovery possible; affording proof that the two types of flight vortices can be identified with the two values of the lift coefficient, one belonging to a high L/D régime, the other to a low L/D régime.

Various experimenters have in the past given evidence of discontinuity of the flow past aerodynamic objects. As applied to aerofoils, Mr. Orville Wright conducted in 1918 a particularly interesting series of experiments, the results of which unfortunately have not been published, wherein new discoveries were brought out regarding the discontinuity of flow about propeller sections. He found that at certain angles thick sections manifested a dual value of the coefficients, the angle at which discontinuity occurred depending on whether the angle was increasing or decreasing at the time when the readings were taken. He interpreted the phenomenon as due to a change of air flow. He found two distinct values of the lift coefficient and of the drift coefficient throughout the range of instability; the high lift value always corresponding to a low drift value and vice versa. It was possible to make the values change back and forth between the two points at will by disturbing the air current.

The writers have been able to verify conclusively Mr. Wright's assumption that his results involved a change of air flow; wherever discontiuity has been encountered in our experiments it has always been found that the drag and lift became discontinuous simultaneously, and that the high value of lift always coincided with the low value of drag.

PRACTICAL SIGNIFICANCE OF THE RESULTS

Reference has already been made to the prospect, opened by these experiments, of developing a usable physical thory of flight. The immediate practical results have also been important, especially as regards propeller design. For example, we have demonstrated the existence of a limited tip speed.

When the critical speed at which the change in flow takes place is reached, there is in some cases a violent chattering of the

model and support; and the nature of the vibrations readily suggests a connection with the fluttering sometimes observed in propellers. The speed encountered is equal to the tip speed of slow-speed propellers, but is considerably inferior to the tip speed of the very large fast-turning propellers used on the Liberty engine.

Many static tests carried out by the writers on propellers have shown an effect which appears to be related to the discoveries made during the series of aerofoil experiments. It is well known that the ratio of propeller thrust to propeller torque must be independent of speed of revolution if both thrust and torque are proportional to the square of the revolutions. It has been found in practice, however, that the ratio of thrust to torque decreases greatly with revolution speed when high tip speeds are reached, and that it sometimes shows a rapid decrease accompanied by violent fluttering. The analogy to the results of the aerofoil tests is obvious and it is felt that considerable study is desirable in order to connect these facts in a rational manner.

We have found by practical experience that if we do not go below a value of V/ND (velocity/r.p.m. of engine $\times$ diameter of propeller) of 0.65 we get a very fair propeller efficiency. As we have gradually increased the speed of our planes we have gone on increasing the r.p.m. of the engine and the diameter of our propellers so that the value of V/ND has remained about the same for the great majority of propellers in actual service.

We have always assumed that there was no limit to this development aside from the characteristics of the plane and engine. That is, we have made the assumption that we could double our propeller speed just as soon as we were able to double our plane speed and strengthen our engine enough to stand the stresses involved.

It now appears, however, as though there is a limit to propeller speed aside from the value of V/ND or, to use more familiar terms, aside from pitch ratio.

Unfortunately, even the speed obtainable in the McCook Field wind tunnel is not great enough to measure the limiting velocity for relatively thin sections when set at low angles, consequently we are only able to infer that it exists.

Conception of Limiting Stress in Fluid Dynamics

Mathematical studies of first importance, which are now classical, on the nature of the flow about an aerofoil have been developed by Helmholtz, Kirchoff, Lord Rayleigh, Lanchester, Prandtl, Kutta, Karman, Greenhill, Lewis and others. Dr. Georges de Bothézat has put forward some very interesting ideas about the effect of stresses in the fluid on the nature of the air flow, and by his theory it is proper to consider in fluid dynamics the same sort of stresses with which we are familiar in solid statics.

It is Dr. de Bothézat's conception that the type of flow which establishes itself is governed by the stresses set up in the air passing the aerofoil. The unit stresses increase as the velocity rises. It is easy to conceive that a given type of flow is possible only so long as the shearing stress, developed in the fluid, does not exceed a certain magnitude which depends on the value of the viscosity coefficient. When the stress reaches a certain critical value, rupture occurs in the air-flow structure; adjacent layers of air begin to slide past each other. Since there is no longer flow similarity, the aerofoil characteristics must change in the manner described earlier in this paper.

BOOK NOTES

American Gas Works Practice. Standard Practical Methods in Gas Fitting. Distribution and Works Management. By George Wherle. Progressive Age Publishing Co., New York, 1919. Cloth, 6 x 8 in., 741 pp., illus., tables, $4.00.

This work is intended as a general reference book on gas-works practice in this country, with special emphasis on gas-fitting practice. Approximately, one-half of the book is given to the latter topic, and the methods used in street and house distribution, standards adopted, etc., are fully described.

Applied Motion Study. A Collection of Papers on the Efficient Method to Industrial Preparedness. By Frank B. Gilbreth and L. M. Gilbreth. The Macmillan Co., New York, 1919. Cloth, 5 x 8 in., 220 pp., plates, 1 chart, $1.50.

This collection describes the application of motion study in various fields of activity and the methods by which it is applied. It also gives the results obtained in various cases and suggests the fields in which it may be used with benefit.

Chilton Automobile Directory, January 1920. Published quarterly by the Chilton Co., Philadelphia. Cloth, 6 x 10 in., 1000 pp., $5.00.

This quarterly directory of the automobile industry contains a classified list of the American manufacturers of passenger and commercial motor-cars, automobile equipment, parts and machinery for their manufacture. The arrangement is alphabetic and the classification is quite detailed.

In addition, the book contains a directory of automobile trade associations, a table of the serial numbers of American motor cars, the standards of the Society of Automotive Engineers and various engineering tables.

Engineering Machine Tools and Processes. A Text-Book for Engineers, Apprentices, and Students in Technical Institutes, Trade Schools and Continuation Classes. By Arthur G. Robson. Longmans, Green & Co., New York, 1919. Cloth, 6 x 9 in., 307 pp., illus., table, $4.00.

This work presents a course in the systematic study of machine work and machine tools which is practical rather than theoretical in character. The methods and machines described are those used in British shops and the volume is intended for use in that country.

Fatigue Study. The Elimination of Humanity's Greatest Unnecessary Waste, a First Step in Motion Study. By Frank B. Gilbreth and Lillian M. Gilbreth. The Macmillan Co., New York, 1919. Cloth, 5 x 8 in., 175 pp., plates, $1.50.

This book is a study of fatigue in workmen and its prevention. It aims to determine what fatigue results from various types of work and how unnecessary fatigue may be eliminated and necessary fatigue reduced to a minimum. Numerous appliances and methods are described.

Highway Inspectors' Handbook. By Prevost Hubbard. First edition. John Wiley & Sons, Inc., New York, 1919. Flexible cloth, 4 x 7 in., 372 pp., 55 illus., diagrams, tables, $2.50.

The author has endeavored to present most of the important details of highway construction and maintenance, as briefly as possible, in such form as to be quickly available to the inspector, who wishes to be told what to do rather than what others have done under similar circumstances. Considerable explanatory matter has been included, and diagrams have been used freely to present data in convenient form for field use.

Manufacture and Uses of Alloy Steel. By Henry D. Hibbard. John Wiley & Sons, Inc., New York, 1919. Cloth, 6 x 9 in., 110 pp., $1.25. (Wiley Engineering Series.)

In this monograph the author has tried to give briefly information of present value relating to the manufacture and uses of the various commercial alloy steels, with the hope of stimulating the demand for them and extending their practical use. The steels considered are tungsten, chromium, manganese, nickel, silicon, nickel-chromium, chromium-vanadium and high-speed tool steels. Bibliographies are given for each.

The Principles of Electrical Engineering and Their Application. Vol. 2. By Gisbert Kapp. Longmans, Green & Co., New York, 1919. Cloth, 6 x 9 in., 388 pp., 173 diag., $6.

The present textbook is intended for all general engineering students and also as a handbook for general engineers. For the latter, the author attempts to provide a work which will give him the fundamental principles of the subject and describe their application in practical engineering, without burdening him with minute details of design. It will, the author hopes, enable the general engineer to determine whether and how any particular piece of electrical plant can be used or adapted for a particular purpose.

Volume 1, dealing with Principles, appeared in 1916. The present volume treats of the applications of these principles in electrical machines.